



TREATISE

OF THE

Animal Oeconomy.

The Second Edition, with Additions.

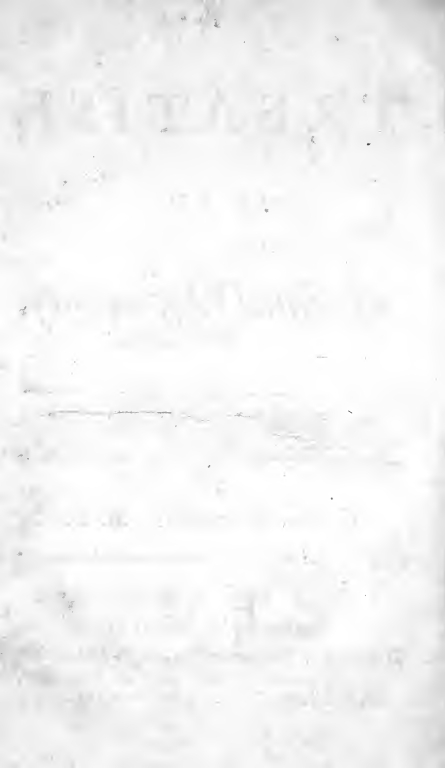
BY

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P R E F A C E.



*I*n the following Treatise I have avoided Hypotheses, and explained the Laws which obtain in human Bodies, by Reason and Experiments. Hypotheses, of whatever Nature, are not to be admitted in Philosophy. Now whatever is not deduced from the Phænomena, is to be called an Hypothesis.

Harvey from Experiments and Observations traced out the Circular Motion of the Blood. After him Lower made some farther Discoveries concerning

cerning that Motion, and the Causes by which it may be disturbed. After these great Men, the Knowledge of the Animal Œconomy received no very considerable Improvement, till Sir Isaac Newton discovered the Causes of Muscular Motion, and Secretion; and likewise furnished Materials for explaining Digestion, Nutrition, and Respiration. To Him I am chiefly indebted for what I have delivered on those Heads.

In this second Edition I have added a Section concerning the Effects of various Fluids, of Age, of different Kinds of Weather, and of Exercise, on animal Fibres.





A

TREATISE

OF THE

Animal Oeconomy.



IN this Treatise I shall give an Account of the principal Parts of the *Animal Oeconomy*; which I shall explain, not by Hypotheses, but by Reason and Experiments. The Parts I shall treat of, are *Muscular Motion, the Motion of the Blood, Respiration,*

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spiration,

spiration, Digestion, Nutrition, Secretion, the Discharges of Human Bodies, and the Effects of various Fluids, of Age, of different Kinds of Weather, and of Exercise, on Animal Fibres.

In order to explain *the Motion of the Blood*, I shall premise an Account of *the Motion of Fluids thro' Cylindrical Pipes*, and prove the Properties of that Motion by Experiments.



SECTION I.

Of the Motion of Fluids through Cylindrical Pipes.

PROPOSITION I.

I *F a given Fluid be moved through a Cylindrical Pipe made of a given Sort of Matter, by a Force acting constantly*

stantly and uniformly during the whole Time of the Motion; its Velocity, setting aside the Resistance of the Air, will be in a Ratio compounded of the subduplicate Ratio of the moving Force directly, and of the subduplicate Ratios of the Diameter and Length of the Pipe taken together inversly. If F denote the moving Force, D and L the Diameter and Length of the Pipe, and V the Velocity with which the Fluid runs through the Pipe; then V will be proportional to $\sqrt{\frac{F}{DL}}$.

For the whole Motion of the Fluid flowing through the Pipe will, like all other Motions, be measured by the Quantity of Matter moved and its Velocity taken together. But the Quantity of Matter moved, is in a Ratio compounded of the Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, of the Velocity wherewith

the Fluid flows through the Pipe, and of the Time of the Motion. For the Quantity of Matter or Weight of Fluid contained in the Pipe, is opposed to the moving Force during the whole Time of its Action, and must be moved by it for every indefinitely short Cylinder of Fluid discharged by the Pipe; that is, for every physical Point in the Length of another Cylindrical Pipe of an equal Diameter with that through which the Fluid flows, and of such a Length as that it can just contain the Quantity of Fluid discharged in the Time of the Motion; which Length being as the Velocity of the Fluid flowing through the Pipe and the Time of the Motion taken together, the Quantity of Matter moved will be in a Ratio compounded of the Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, of the Velocity

locity wherewith it flows through the Pipe, and of the Time of the Motion. And the whole Motion, which is as the Quantity of Matter moved and its Velocity taken together, will be in a Ratio compounded of the simple Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, and of the Time of the Motion; and of the duplicate Ratio of the Velocity: Therefore, putting T for the Time of the Motion, and Q for the Quantity of Matter or Weight of Fluid contained in the Pipe; the whole Motion will be as QTV^2 .

Setting aside the Resistance of the Air, this Motion would be proportional to the moving Force and Time of its acting taken together, that is, QTV^2 would be proportional to FT , if the internal Surface of the Pipe, by Friction, or Attraction, or both, did not act continually upon

upon the Fluid moving through it, and cause a Change in its Motion proportional to the Efficacy where-with it acts; which Efficacy in a Pipe made of a given Sort of Matter, is measured by the Ratio of the internal Surface of the Pipe to the Quantity of Fluid contained in it; that is, by DL applied to Q . And by Consequence $\frac{QTV \cdot DL}{Q}$ will be proportional to FT : Whence V will be proportional to $\sqrt{\frac{F}{DL}}$.

Cor. 1. If the moving Force and Diameter of the Pipe, be both given, or be proportional to each other; the Velocity, setting aside the Resistance of the Air, will be in the inverse subduplicate Ratio of the Length of the Pipe. If F and D be given, or if F be as D ; V will be as $\frac{1}{\sqrt{L}}$.

Cor.

Cor. 2. If the moving Force be as the Quantity of Fluid contained in the Pipe; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe and Density of the Fluid taken together. Putting Δ for the Density of the Fluid, if F be as $D^2 L \Delta$; then V will be as $\sqrt{D \Delta}$.

Cor. 3. If the moving Force be as the Quantity of Fluid contained in the Pipe, and the Density of the Fluid be given; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe. If F be as $D^2 L \Delta$, and Δ be given; then V will be as \sqrt{D} .

Cor. 4. If the moving Force be proportional to the Square of the Diameter of the Pipe, and the
Length

Length of the Pipe be given, or if the moving Force be as the Capacity of the Pipe; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe. If F be as D^2 , and L be given, or F be as $D^2 L$; then V will be as \sqrt{D} .

Cor. 5. If the moving Force be as the Square of the Diameter of the Pipe; the Velocity, setting aside the Resistance of the Air, will be in a Ratio compounded of the subduplicate Ratio of the Diameter of the Pipe directly, and of the subduplicate Ratio of its Length inverſly. If F be as D^2 ; then will V be as $\sqrt{\frac{D}{L}}$.

Cor. 6. If the moving Force be as the Capacity of the Pipe, and the Diameter of the Pipe be in the sub-

subduplicate Ratio of its Length ; the Velocity, setting aside the Resistance of the Air, will be in the subquadruplicate Ratio of the Length of the Pipe. If F be as D^2L , and D be as \sqrt{L} ; then will V be as $L^{\frac{1}{4}}$.

Cor. 7. The moving Force, setting aside the Resistance of the Air, will be in a Ratio compounded of the duplicate Ratio of the Velocity, and of the simple Ratios of the Diameter and Length of the Pipe. F will be as V^2DL .



Proof by Experiments.

TO prove the Truth of this Proposition by Experiments, I procured several Cylindrical Pipes of Brass, of different Diameters
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and

and Lengths; each of which Pipes had one End fitted to screw into the Side of a Vessel filled with Water, at three different Distances from its Top, namely, at the Distances of one Foot, two Feet, and four Feet. The Vessel made for these Experiments, was a square Wooden Vessel something above four Feet in Depth, and nine Inches of a *London* Foot in its internal Length and Breadth.

Before I give an Account of the Experiments, it will be necessary to shew how to measure the moving Forces and Velocities of Water, flowing through Cylindrical Pipes screwed into the Side of a Vessel filled with Water.

To measure the moving Force of Water flowing through a Cylindrical Pipe, screw'd into the Side of a Vessel filled with Water; we must know the Area of the Top of the Water

Water in the Vessel, the Area of the Orifice of the Pipe, the perpendicular Distance of the Place of the Pipe's Insertion into the Side of the Vessel from the Top of the Water, and the Situation of the Pipe with respect to the Horizon.

Let the Area of the Top or upper Surface of the Water in the Vessel be called A, the Area of a Hole made in the Bottom or Side of the Vessel be called a, and the perpendicular Distance of the Hole or Place of Insertion of the Pipe from the Top of the Water be called H; and then, by *prop. 36. lib. 2. Princip. Newton.* the Velocity of the Water flowing out of the Hole, setting aside the Resistance of the Air, will be equal to the Velocity which a heavy Body would acquire in falling perpendicularly and without Resistance thro' the Space $\frac{A^2 H}{A^2 - a^2}$. And,

by the second *Corollary* of the same *Proposition*, the Force generating the whole Motion of the effluent Water, will be equal to the Weight of a Cylinder of Water, whose Base is $\frac{12}{17}$ Parts of the Area of the Hole, or a , and whose Height is $\frac{2A^2H}{A^2 - a^2}$. If the Area of the Hole, be exceeding small when compared with the Area of the upper Surface of the Water, that is, if a be exceeding small when compared with A ; the Height $\frac{2A^2H}{A^2 - a^2}$ will be very nearly equal to $2H$; and by Consequence, the Force generating the whole Motion of the effluent Water, will be very nearly equal to the Weight of a Cylinder of Water, whose Base is $\frac{12}{17}a$, and whose Height is $2H$; that is, very nearly equal to the Weight of the Cylinder $\frac{24}{17}aH$: But the Weight of this Cylinder is proportional to the
 Weight

Weight of the Cylinder aH, because $\frac{24}{17}$ is an invariable Quantity: And therefore, when the Area of the Hole is extremely small in comparison of the Area of the Top of the Water, the Force generating the whole Motion of the effluent Water, will be very nearly proportional to the Weight of the Cylinder aH.

The Force generating the Motion of Water flowing thro' a Cylindrical Pipe screw'd into the Side of a Vessel fill'd with Water, and laid parallel to the Horizon, is something greater than the Force generating the Motion of Water flowing through a Hole whose Diameter is equal to that of the Pipe, and which is placed at an equal Distance from the Top of the Water; as will appear by considering the Nature of these two Motions.

In

In observing the Motion of Water flowing through a Hole made in the Side of a Vessel, we may perceive the Vein not to fill the Hole. Sir *Isaac Newton*, in determining this Motion from Experiments, found the Vein, after it had passed out of the Hole, to grow smaller and smaller, till it came to a Distance very nearly equal to the Diameter of the Hole; at which place he measured the Diameter of the Vein, and found it to be to the Diameter of the Hole, as 21 to 25. The Area of a transverse Section of the Vein at that Distance from the Hole, is to the Area of the Hole; as the Square of the Diameter of the Vein, to the Square of the Diameter of the Hole; that is, as 12 is to 17 nearly. This Contraction of the Vein arises from the Nature of the Motion of the Water down the Vessel: For the Water falls
down

down from the Top of the Vessel to the Hole not perpendicularly but obliquely, its Parts moving laterally as well as downwards. From the Obliquity of this Motion it is, that the Column of the descending Water grows narrower perpetually from the Top of the Water to the Hole, and to a small Distance beyond it; and that the Vein does not fill the Hole, but falls within it, leaving a little empty Space all round. On account of this Contraction of the Vein, less Water flows out, and by Consequence less Motion is generated in a given Time, than would be produced, if the Diameter of the Vein at the Hole was exactly equal to the Diameter of the Hole. And as less Motion is generated, so the moving Force is likewise less; being only equal to the Weight of a Cylinder of Water, whose Magnitude is $\frac{24}{17} aH$, when the Hole is extremely

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ly small in comparison of the upper Surface of the Water ; whereas it would be equal to the Weight of a Cylinder of Water whose Magnitude is $2aH$, if the Vein filled the Hole and had no Contraction beyond it. And therefore the moving Force is less than it would be if the Vein filled the Hole and had no Contraction beyond it, in the Proportion of 12 to 17.

If instead of flowing through the Hole into the open Air, the Water flows through the Hole into a Cylindrical Pipe, and through that into the Air ; and if the Diameter of the Hole be equal to that of the Pipe ; the Force generating the Motion of the Water flowing through the Pipe, will be different from the Force generating the Motion of the Water flowing through the Hole.

First,

First, let us suppose the Pipe to lie parallel to the Horizon; and then the Force generating the Motion of the Water flowing thro' it, will be greater than the Force generating the Motion of the Water flowing thro' the Hole. For the Weight of Water in the Pipe, and the Resistance arising from the internal Surface of the Pipe, do both of them, by acting in a kind of Opposition to the Weight of the descending Cataract in the Vessel, retard the Motion of the Cataract, and hinder it from flowing so fast into the Pipe, as it does thro' the Hole into the open Air. And by this Opposition, they make the Base of the Cataract at its Entrance into the Pipe, to spread and grow broader; and by Consequence, encrease the moving Force, and make it greater than the Force generating the Motion of the Water flowing

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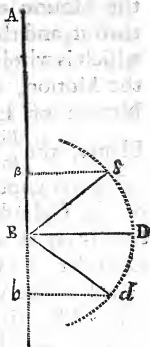
thro' the Hole. Hence it is evident, that the moving Force will encrease, either on encreasing the Length of the Pipe or lessening its Diameter; and will be greatest, when the Pipe is infinitely long or infinitely narrow: In which Cases, the Base of the Cataract at its Entrance into the Pipe, will exactly fill it; and the moving Force will be equal to the Weight of a Cylinder of Water, whose Magnitude is $2 a H$; and by Consequence will be greater than the Force generating the Motion of the Water flowing thro' the Hole, in the Proportion of 17 to 12; and the Motion generated in the Water flowing thro' the Pipe, will be greater than the Motion generated in the Water flowing thro' the Hole; and the Difference of these two Motions will be greater when the Pipe is long or narrow, than when it is short or wide. And there-

therefore, if we suppose the Forces generating the Motions of Water flowing thro' Cylindrical Pipes laid parallel to the Horizon, to be equal to the Forces generating the Motions of Water flowing thro' Holes of equal Diameters, and placed at equal perpendicular Distances from the upper Surface of the Water in the Vessel; on which Supposition the Force generating the Motion of Water flowing thro' a Pipe, will be proportional to the Weight of a Cylinder of Water whose Magnitude is aH , the Motion of the Water flowing thro' a longer or a narrower Pipe, when compared with the Motion of the Water flowing thro' a shorter or a wider Pipe, will be found by Experiments, to be something greater than it ought to be on this Supposition of the moving Force. But the Difference will be but small in Pipes of small

Lengths and Diameters; and therefore in the following Experiments, when a Pipe lies horizontally, I shall suppose the moving Force to be proportional to the Weight of the Cylinder aH .

The moving Force will become different, when the Pipe is inclined to the Horizon. The Weight of Water in the Pipe, as far as it increases or lessens the Motion generated by the Force, which is proportional to the Weight of the Cylinder aH , must be added to or subducted from that Weight; and the Sum or Difference, will be proportional to the Force generating the Motion of the Water flowing thro' the Pipe in that inclined Position. That part of the Weight of the Water in the Pipe, which is to be added to or subducted from the Weight of the Cylinder aH , may be thus determined. Let BD represent

present a Cylindrical Pipe, lying parallel to the Horizon, with its End B inserted into the Side of a Vessel at the perpendicular Distance of BA from the Top of the Water; the Force generating the Motion of the Water flowing thro' this Pipe, is proportional to the Weight of the Cylinder $a \times AB$; because in this Case H is equal to AB. Let the Pipe be turned



from its horizontal Position, either downwards into the Position Bd, or upwards into the Position B_s; and then the moving Force will be changed, and be proportional to the Weight of the Cylinder $a \times Ab$ in the first Case, and to the Weight of the Cylinder $a \times A_{\beta}$ in the

the

the second. For the Weight of the Water in the Pipe Bd, on account of its inclined Situation, encreaseth the Motion of the Water flowing thro' it, and that part of this Weight, which is wholly spent in encreasing the Motion, is, from the Laws of Motion of Bodies down inclined Planes, the $\frac{Bb}{Bd}$ part of the Weight of Water contained in the Pipe, or of the Cylinder $a \times Bd$; and therefore is equal to the Weight of the Cylinder $a \times Bb$. This Weight added to the Weight of the Cylinder $a \times AB$, gives the Weight of the Cylinder $a \times Ab$; which Weight is the Force generating the Motion of the Water flowing thro' the Pipe Bd. The Weight of Water in the Pipe B, lessens the Motion of the Water flowing thro' it, and that part of the Weight which is wholly spent in lessening the Motion, is the Weight
of

of the Cylinder $a \times B\beta$. This Weight subducted from the Weight of the Cylinder $a \times AB$, leaves the Weight of the Cylinder $a \times A\beta$, which Weight is the Force generating the Motion of the Water flowing thro' the Pipe $B\alpha$.

If B be made the Center of a Circle, and Bd or $B\alpha$ the Radius, Bb will be the right Sine of Bdb the Angle of the Pipe's Depression below the Plane of the Horizon; and $B\beta$ will be the right Sine of $B\alpha\beta$ the Angle of its Elevation above it. And by Consequence, when the Pipe is depressed below the Horizon, the moving Force will be proportional to the Weight of a Cylinder of Water, whose Base is equal to the Orifice of the Pipe, and whose Altitude is equal to the Sum of the perpendicular Height of the Water in the Vessel above the place where the Pipe is inserted, and the right Sine

Sine of the Angle of Depression of the Pipe below the Plane of the Horizon: And when the Pipe is elevated above the Horizon, the moving Force will be proportional to the Weight of a Cylinder of Water, whose Base is equal to the Orifice of the Pipe, and whose Height is equal to the Difference of the perpendicular Height of the Water in the Vessel above the place of Insertion, and the right Sine of the Angle of Elevation of the Pipe above the Plane of the Horizon. If S denotes the right Sine of the Angle, in which the Pipe is depressed below or elevated above the Plane of the Horizon; the moving Force will be proportional to the Weight of the Cylinder $a \times \overline{H+S}$, when the Pipe is depressed below the Horizon, and proportional to the Weight of the Cylinder $a \times \overline{H-S}$, when it is elevated above it; and comprehending both

both Cases in one Expression, the moving Force will be as $a \times \overline{H \pm S}$, or as $D^2 \times \overline{H \pm S}$, very nearly.

So then the Velocity of Water flowing thro' a Cylindrical Pipe screw'd into the Side of a Vessel filled with Water, will be measured by $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$. For by this *Proposi-*

tion V is as $\sqrt{\frac{F}{DL}}$: But F is as $D^2 \times \overline{H \pm S}$:

And therefore V is as $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$.

Another Measure of it may be had from Experiments. For the Velocity of Water flowing thro' a Cylindrical Pipe, lying either parallel or inclined to the Horizon, is proportional to the Quantity of Water discharged in a given Time, apply'd to the Orifice of the Pipe. For the Quantity discharged in a given Time, apply'd to the Orifice of the Pipe, will give the Length of a Cy-

D lindrical

lindrical Pipe which can just contain that Quantity ; which Length is the Space that would be described in the Time of the Motion by an uniform Velocity, equal to the Velocity with which the Fluid flows thro' the Pipe when the moving Force acts constantly and uniformly, as it will do if the Vessel be kept constantly full, by pouring in Water very gently at the Top as fast as it runs out of the Pipe. But the Velocities of all uniform Motions are as the Spaces described in a given Time ; and by Consequence, the uniform Velocity with which the Length of the said Cylinder would be described in the given Time of the Motion, will be proportional to that Length ; and therefore proportional to the Quantity of Fluid discharged apply'd to the Orifice of the Pipe. Let M denote the Quantity of Water discharged in the
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the given Time of the Motion; and then the Velocity V will be proportional to, and consequently measured by, $\frac{M}{a}$ or $\frac{M}{D^2}$ because Circles are to one another as the Squares of their Diameters.

If the Velocity be rightly measured by this *Proposition*, then $\sqrt{\frac{D \times H \pm S}{L}}$

must be proportional to $\frac{M}{D^2}$ very nearly; as it will appear to be by the following Experiments, setting aside the Resistance of the Air.

Tho' in this *Proposition* I have set aside the Resistance given by the Air to this Motion, yet it will be necessary to consider it, in order rightly to understand the Disturbances in the Motion caused by it. Water in flowing out of a Pipe into the open Air, communicates a Motion to the Air, and loses so much

of its own Motion as it communicates. Now if we suppose the Motion communicated to be proportional to the Square of the Diameter of the Vein of the effluent Water, and the Square of its Velocity, taken together; then the Motion communicated to the Air, with respect to the Motion which in the same Time would be generated in the Water, setting aside the Resistance of the Air, and that which arises from the internal Surface of the Pipe, will be reciprocally as the Length of the Pipe. And by Consequence, in Pipes of the same Length, the Motions communicated to the Air, will on this Supposition be proportional to those which would be generated in the Water if there was no Air, nor any Resistance arising from the internal Surfaces of the Pipes. And therefore the Resistance of the Air will
cause

cause no Disturbance in the Proportions of the Motions of the Water flowing thro' such Pipes. This Supposition, that the Veins of the effluent Water are resisted by the Air, in Proportion to the Squares of their Diameters and the Squares of their Velocities, taken together, will not appear unreasonable, when we consider that solid Globes in moving thro' the Air, are resisted in that Proportion.

Experiment 1. Three Cylindrical Pipes, whose Lengths were two, four, and eight Feet, and whose common Diameter was $\frac{345}{1000}$ parts of an Inch, were one after another screwed into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and laid parallel to the Horizon. These three Pipes thus situated, discharged 175, 133, and $97\frac{1}{2}$ Troy Ounces of Water in half

a Minute, The Pipes having equal Diameters, the Velocities of the Water flowing thro' them were as the Quantities of Water discharged in equal Times; that is, as the Numbers 175, 133, and $97\frac{1}{2}$: For when D is given, V is as M. By the other Measure of the Velocity deduced from this *Proposition*, the Velocities ought to have been reciprocally as the Square Roots of the Lengths of the Pipes; that is, nearly as the Numbers 20000, 14142, and 10000. For the Pipes having equal Diameters, being all inserted into the Side of the Vessel at the same perpendicular Distance from the Top of the Water, and all laid parallel to the Horizon; D and H were given, and S was 0; and consequently the Velocity, which I have shewn to be measured by $\sqrt{\frac{D \times H \pm S}{L}}$, ought in the present Case

to have been as $\frac{1}{\sqrt{L}}$. The Velocities from this Measure are nearly proportional to those from Experiments. Those from Experiments with respect to these, are as the Numbers 175, 188, 195 : whence it appears, that the Velocity from Experiment, with respect to the Velocity expressed by the other Measure, is something greater in the longer of any two of these Pipes than in the shorter ; as it ought to be, from what has been said, both on account of the Resistance of the Air, and the Nature of the moving Force.

Experiment 2. Three Cylindrical Pipes, whose Lengths were equal, and whose Diameters were $\frac{372}{1000}$, $\frac{185}{1000}$, and $\frac{90}{1000}$ parts of an Inch, being one after another screw'd into the Side of the Vessel, at the perpendicular Distance of four Feet from the Top
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of the Water, and laid parallel to the Horizon, discharged 179, 33 $\frac{1}{2}$, and 6 $\frac{1}{8}$ Ounces of Water in half a Minute. The Velocities, found by dividing these Quantities by the Squares of the Diameters of their respective Pipes; were as the Numbers 1293, 979, and 756. By the other Measure they ought to have been as the Square Roots of the Diameters of the Pipes; that is, nearly as the Numbers 193, 136, and 94. For the Pipes having equal Lengths, being all inserted into the Side of the Vessel at the same perpendicular Distance from the Top of the Water, and being laid parallel to the Horizon; L and H were given, and S was 0; consequently $\sqrt{\frac{D \times H \pm S}{L}}$ was in this Case as \sqrt{D} . The Velocities from this Measure are nearly proportional to those from Experiments. Those from

from Experiments, with respect to these, are as the Numbers 670, 720, 804; whence it appears, that the Velocity from Experiment, with respect to what it ought to be by the Measure of this *Proposition*, is something greater in the narrower of any two of these Pipes than in the wider; as I have shewn it ought to be, from the Nature of the moving Force.

Experiment 3. Two Cylindrical Pipes, whose Lengths were eight Feet and two Feet, and whose Diameters were $\frac{345}{1000}$ and $\frac{185}{1000}$ parts of an Inch, were screw'd into the Side of the Vessel at the perpendicular Distances of four Feet, and one Foot from the Top of the Water, and were laid parallel to the Horizon. These Pipes thus fixed discharged $87\frac{1}{2}$, and 16 Ounces of Water in half a Minute. The Velocities in them, found by dividing their Discharges

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by the Squares of their Diameters, were nearly as the Numbers 73, and 46. By the other Measure of the Velocity they ought to have been as the Square Roots of the Diameters of the Pipes; that is, nearly as the Numbers 186 and 136: For H and L were each of them four in the first Experiment, and one in the second, and S was nothing in both; and consequently the Velocity, expressed by $\sqrt{\frac{D \times H \pm S}{L}}$, in the present Case was as \sqrt{D} . The Velocity in the Pipe which was nearer to the Top of the Vessel, was less than it ought to have been by this Measure, in the Proportion of 34 to 39. And in all the Experiments I have made upon this Occasion, I have always found the Velocities in the same Pipes placed at different Distances from the Top of the Water, to be less at less Distances from the Surface

Surface than at greater, with respect to what they ought to have been by this *Proposition*. This Defect of Velocity may be owing, partly to a Disturbance given to the Motion by the Water, which was poured in at the Top of the Vessel in order to keep it constantly full, which Disturbance, being greater at a less Distance from the Surface, might cause a greater Loss of Motion; and partly to the moving Force's being in reality something greater at a greater Distance from the Top of the Water, than it ought to be by the Measure I have given of it.

Experiment 4. Two Cylindrical Pipes of equal Diameters, and of the Lengths 1 and 4, were one after the other screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and were each of

E 2 them

them depressed in an Angle of 30 Degrees below the Plane of the Horizon. These Pipes thus situated discharged $41\frac{3}{8}$ and $25\frac{5}{8}$ Ounces of Water in half a Minute. The Velocities in these Pipes, on account of their having equal Diameters, were as the Quantities discharged. By the other Measure they ought to have been as the Numbers 300 and 173. For the Pipes having equal Diameters, and being both depressed below the Horizon, that Measure became $\sqrt{\frac{H+S}{L}}$. The natural Sine of 30 Degrees being equal to half the Radius, S was half a Foot for the shorter Pipe, and two Feet for the longer; and $\frac{H+S}{L}$ was $4\frac{1}{2}$ for the first, and $\frac{4}{3}$ or $1\frac{1}{3}$ for the second; or 9 for the first, and 3 for the second. But the Square Roots of 9 and 3 are as the Numbers 300 and 173, which Numbers are nearly

ly in the same Proportion as the Numbers $41\frac{3}{8}$, and $25\frac{5}{8}$; and therefore the Velocities were nearly in the same Proportion, as they ought to have been by this *Proposition*.



PROPOSITION II.

IF a given Fluid flows through two Systems of Cylindrical Pipes made of a given Sort of Matter, and consisting each of one Trunk, and the same Number of Branches arising from it; if the Pipes of the two Systems have like Situations and Capacities, that is, if any two corresponding Pipes be similarly situated with respect to the rest of the Pipes, and their Capacities be as the Capacities of the whole Systems; And if the Forces generating the Motions in two corresponding Pipes be in the same

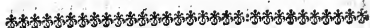
same Proportion as the whole moving Forces of the two Systems: The Velocities in the two corresponding Pipes, setting aside the Resistance of the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and of the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inversly. If V, v be put for the Velocities in the two Pipes; D, d , and L, l for their Diameters and Lengths; and F, f for the whole moving Forces of the two Systems; I say, that $V, v :: \sqrt{\frac{F}{DL}} \cdot \sqrt{\frac{f}{dl}}$.

For by the *First Proposition*, the Velocities in any two corresponding Pipes of the two Systems, setting aside the Resistance of the Air, are to each other in Ratios compounded of the subduplicate Ratios of the

the

the Forces generating the Motions in the two Pipes directly, and of the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inverſly : But by Suppoſition the Forces generating the Motions in the two Pipes are in the ſame Proportion as the whole moving Forces of the two Systems: And therefore by Proportion of Equality, the Velocities in the two correſponding Pipes, ſetting aſide the Reſiſtance of the Air, will be in Ratios compounded of the ſubduplicate Ratios of the whole moving Forces of the two Systems directly, and of the ſubduplicate Ratios of the Diameters and Lengths of the two Pipes inverſly.



*Proof by EXPERIMENTS.**Experiment I.*

I Had two Systems of Cylindrical Pipes made of Brass, each of which consisted of a Trunk and two Branches. The larger Branch of each System was a Continuation of its Trunk, having an equal Diameter, and lying in a right Line with it; and the smaller Branch of each made an Angle of 30 Degrees with the larger. The Trunks and Branches of the two Systems were each of them one Foot in Length; the Diameter of the Trunk and larger Branch in the greater System was $\frac{345}{1000}$, and the Diameter of the smaller Branch $\frac{187}{1000}$ parts of an Inch; and the Diameter of the Trunk and larger

larger Branch in the lesser System was $\frac{187}{1000}$, and the Diameter of the smaller Branch $\frac{90}{1000}$ parts of an Inch. The Trunks of these two Systems were successively screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and were turned till their Branches lay parallel to the Horizon. In this Situation, the Branches of the greater System discharged $169\frac{1}{2}$ and 20, and the Branches of the lesser $30\frac{3}{4}$ and 4 Ounces of Water in half a Minute. The Velocities in the Trunks and Branches of these Systems, found by dividing the Quantities which flow'd thro' them in a given Time by the Squares of their respective Diameters, were as the Numbers 1592, 1424, and 572 in the Trunk and Branches of the greater System; and as the Numbers 979, 865, and 494 in the Trunk and Branches of

F the

the leffer. The Quantities of Water contained in these two Systems, were as the Numbers 273 and 78; as I found by multiplying the Squares of the Diameters of the several Pipes into their Lengths, and then adding the Products of each System into one Sum. Since all the Pipes of the two Systems were at the same perpendicular Distance from the Top of the Water, and lay parallel to the Horizon, in which Position the Weights of Fluid contained in the Pipes made no part of the Forces generating the Motions of the Water flowing thro' them, the Forces generating the Motions in the Trunks and corresponding Branches, were as the Squares of their Diameters, or as the Quantities of Water contained in them, because they all had the same Length. And therefore had these two Systems been truly made, so as
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to have had the Conditions required in the *Proposition*, that is, had the Quantities of Water contained in the Trunks and corresponding Branches been exactly proportional to the whole Quantities of Water contained in the two Systems; the Velocities in those Pipes, setting aside the Resistance of the Air, ought to have been in the subduplicate Ratios of their Diameters directly. But the Capacity of the lesser Branch of the greater System compared with the Capacity of that System, was greater than the Capacity of the lesser Branch of the lesser System compared with the Capacity of its System, in the Proportion of 5 to 4 nearly. The Velocity by Experiment in the lesser Branch of the greater System compared with the Velocity by the Theory, was less than it would have been had the Branch

been truly constructed; which agrees with what I have already shewn both from Experiments and Reason, namely, that in Pipes of different Diameters but equal Lengths the Velocity by Experiment compared with the Velocity by the Theory, is always greatest in the narrowest Pipes. The Velocity by Experiment with respect to the Velocity measured by the Square Root of the Diameter of the Pipe, was less in the smaller Branch of the greater System than in the smaller Branch of the lesser System, in the Proportion of 21 to 26. As the Capacity of the smaller Branch with respect to the Capacity of the System, was something greater in the greater System than in the lesser; so the Capacity of the Trunk or larger Branch with respect to the Capacity of the System, was on the contrary something less in the
greater

greater System than in the lesser ; and by Consequence, from what has been said concerning the Nature of the moving Force, the Velocity by Experiment with respect to the Velocity measured by the Square Root of the Diameter of the Pipe, was greater in the Trunk and larger Branch of the greater System, than it was in the Trunk and larger Branch of the lesser : In the Trunk it was greater in the Proportion of 43 to 36, and in the Branch it was greater in the Proportion of 76 to 63. These Deviations of the Theory from Experiments, are not Objections against it, but rather Arguments of its Truth ; since they all arise, and may be accounted for, from the Systems not having exactly the Conditions required in this *Proposition*.

Experiment II. Two Systems of Cylindrical Pipes, the lesser of which
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was the greater of the two Systems used in the last Experiment, and the greater a System four times as large, its Trunk and Branches having the same Diameters, and being four times as long as the Trunk and Branches of the lesser, had their Trunks successively screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and had both their Trunks and Branches laid parallel to the Horizon : In this Position the Branches of the greater System discharged $90\frac{3}{4}$, and $13\frac{1}{2}$; and the Branches of the lesser $169\frac{1}{2}$, and 20 Ounces of Water in half a Minute. The Diameters of the Trunks and corresponding Branches of the two Systems being equal; the Velocities in those Pipes were as the Weights or Quantities of Water which flow'd thro' them in a given Time, that is, as the Numbers

$104\frac{1}{4}$,

104 $\frac{1}{4}$, 90 $\frac{3}{4}$, 13 $\frac{1}{2}$ in the Trunk and Branches of the greater System; and as the Numbers 189 $\frac{1}{2}$, 169 $\frac{1}{2}$, 20 in the Trunk and Branches of the lesser. The Diameters of the corresponding Pipes of the two Systems being equal, and the Pipes lying parallel to the Horizon, and at the same perpendicular Distance from the Top of the Water; D and H were given, and S was 0; and consequently the other Measure of the

Velocity $\sqrt{\frac{D \times H \pm S}{L}}$ in this became

$\frac{1}{\sqrt{L}}$. Whence the Velocities in the corresponding Pipes of the Systems ought to have been in the inverse subduplicate Ratios of the Lengths of those Pipes, that is, they ought to have been twice as great in the Trunk and Branches of the shorter System as in the Trunk and corresponding Branches of the longer,
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as they nearly were; only they were something greater in the longer System than they ought to have been, partly from a less Resistance of the Air, and partly from the Nature of the moving Force, which from what has been said concerning its Measure, was something greater in the longer System than in the shorter.

Experiment III. I placed the two Systems, used in the last Experiment, at different perpendicular Distances from the Top of the Water, with their Trunks and Branches parallel to the Horizon; and always found the Velocities in the Trunk and Branches of each System, to be nearly in the subduplicate Ratios of the perpendicular Distances of the System from the Top of the Water; only at less Distances they were something less than they ought to have been by this Measure, for the
Reasons

Reasons assigned in the third Experiment of the first *Proposition*.

Experiment IV. The two Systems used in the second and third Experiments, were one after the other screw'd into the Side of the Vessel at different perpendicular Distances from the Top of the Water, the lesser at the Distance of one Foot; and the greater at the Distance of four Feet; and were turned till the lesser Branch of each System was depressed in an Angle of 30 Degrees below the Plane of the Horizon, while the Trunk and larger Branch of each System lay parallel to it: In these Situations, the Branches of the greater System discharged $89\frac{1}{2}$, $17\frac{1}{8}$; and the Branches of the lesser 79 , $13\frac{1}{4}$ Ounces of Water in half a Minute. The Diameters of the corresponding Pipes being equal; the Velocities in them were as the Quantities of Water which flowed

thro' them in the given Time of the Motion, that is, as $106\frac{5}{9}$, $89\frac{1}{2}$, $17\frac{1}{8}$ in the Trunk and Branches of the greater System; and as $92\frac{1}{4}$, 79 , $13\frac{1}{4}$ in the Trunk and Branches of the lesser. The Diameters of the corresponding Pipes being equal, and the perpendicular Distances of the Systems from the Top of the Water being as the Lengths of the Systems, and the Systems being situated alike with respect to the Horizon; D and S were given, and H was proportional to L; consequently in this Case the other Measure of the Velocity became a given Quantity; whence the Velocities in the corresponding Branches ought by that Measure to have been equal. Their Differences were not great, and probably arose chiefly from the lesser System being placed nearer to the Top of the Water than the greater.



PROPOSITION III.

IF a given Fluid flows thro' two Systems of Cylindrical Pipes made of a given Sort of Matter, and consisting each of two Trunks, and the same Number of Branches similar in their Situations and Capacities, that is, if any two corresponding Pipes be similarly situated with respect to the rest of the Pipes, and their Capacities be as the Capacities of their whole Systems, if in each System the last and smallest Branches of the two Trunks be continuous, and if the Forces generating the Motions in any two corresponding Pipes be in the same Proportion as the whole moving Forces of the two Systems; The Velocities in those Pipes, setting aside the Resistance of the Air, will be in Ratios

compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and of the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inverſly, that is,

$$V . v :: \sqrt{\frac{F}{DL}} : \sqrt{\frac{f}{d l}}$$

For by the *First Proposition*, the Velocities in any two corresponding Pipes of the two Systems, ſetting aſide the Reſiſtance of the Air, are in Ratios compounded of the ſubduplicate Ratios of the Forces generating the Motions in thoſe Pipes directly, and of the ſubduplicate Ratios of their Diameters and Lengths taken together inverſly: But by Suppoſition, the Forces generating the Motions in two correſponding Pipes, are as the whole moving Forces of the two Systems: And therefore by Proportion of Equality, the Velocities in two

cor~

corresponding Pipes, setting aside the Resistance of the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and of the subduplicate Ratios of the Diameters and Lengths of those Pipes taken together inversely.



Proof by EXPERIMENTS.

TO confirm the Truth of this *Proposition* by Experiments, I got made of Brass two such Systems of Cylindrical Pipes as are represented in these Figures. Each System consisted of two Trunks and five Branches all lying in one and the same Plane. The Trunks and Branches of each had equal Diameters

meters and Lengths. The common Diameter of the Trunks and Branches of the greater System, was $\frac{187}{2000}$; and the common Diameter of the Trunks and Branches of the lesser System, was $\frac{92}{1000}$ parts of an Inch. The common Length of the Trunks and Branches of the greater System, was half a Foot; and the common Length of the Trunks and Branches of the lesser, three Inches. The Trunks of each System opened into the Branches, thro' two pyramidal Spaces, which were each three Inches long in the greater System, and an Inch and a half in the lesser; and their Capacities were nearly in the same Proportion as the Capacities of their Trunks or Branches, that is, in the Proportion of 87 to 10. When the Ends F and f were screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of
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the Water, and the Systems were turned till their Branches lay parallel to the Horizon; their other Ends G and g discharged $36\frac{5}{8}$ and $6\frac{1}{8}$ Ounces of Water in half a Minute. The Velocities in the Trunks, found by dividing the Discharges by the Squares of their Diameters, were as the Numbers 1047 and 1003 nearly. And by this *Proposition* they ought to have been as the Numbers 883 and 866, which are proportional to the Numbers 1047 and 1003 very nearly. And since the Systems were similar, and similarly situated, no Doubt can be made, but that the Velocities in corresponding Branches were likewise in the same Proportion.





PROPOSITION IV.

IF a given Fluid flows thro' two compounded Systems of Cylindrical Pipes, consisting each of two Cylindrical Trunks, and the same Number of smaller Systems like those described in the last Proposition, the Trunks of which smaller Systems open into their respective principal Trunks of the compounded Systems, if all the corresponding Pipes of the compounded Systems have like Situations and Capacities, that is, if any two corresponding Pipes be similarly situated with respect to the rest of the Pipes, and their Capacities be in the same Proportion as the whole Capacities of the compounded Systems; and if the Forces generating the Motions in any two corresponding Pipes be as
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the whole moving Forces of the two compounded Systems; the Velocities in those Pipes, setting aside the Resistance of the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two compounded Systems directly, and of the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inversely, that is, $V . v :: \sqrt{\frac{F}{DL}} \cdot \sqrt{\frac{f}{d l}}$

The Demonstration of this *Proposition* is the same with that of the last, and therefore need not be repeated.

Cor. 1. If the whole moving Forces of the two compounded Systems be as the Capacities of those Systems, that is, as the Capacities of any two corresponding Pipes; the Velocities in those Pipes, setting
H aside

aside the Resistance of the Air, will be in the subduplicate Ratios of their Diameters. If $F . f :: D^2 L . d^2 l$; then will $V . v :: \sqrt{D} . \sqrt{d}$.

Cor. 2. If the whole moving Forces of the two compounded Systems be as the Capacities of the Systems, that is, as the Capacities of any two corresponding Pipes, and the Diameters of corresponding Pipes be in the subduplicate Ratios of their Lengths, or of the Lengths of the Systems; the Velocities in corresponding Pipes, setting aside the Resistance of the Air, will be in the subquadruplicate Ratios of the Lengths of the Systems. If $F . f :: D^2 L . d^2 l$, and $D . d :: \sqrt{L} . \sqrt{l}$; then will $V . v :: L^{\frac{1}{4}} . l^{\frac{1}{4}}$.

Cor. 3. If the whole moving Forces of the two compounded Systems be as the m Power of their
Capa-

Capacities, and consequently as the m Power of the Capacities of any two corresponding Pipes, and the Diameters of those Pipes be as the n Power of their Lengths, or as the n Power of the Lengths of the Systems; the Velocities in two such Pipes, setting aside the Resistance of the Air, will be in the $\frac{2nm + m - n - 1}{2}$ Power of the Lengths of the Systems. If $F . f :: D^2 L^m . d^2 l^m$, and $D . d :: L^n . l^n$; then will $V . v :: L^{\frac{2nm + m - n - 1}{2}} . l^{\frac{2nm + m - n - 1}{2}}$.

Cor. 4. The whole moving Forces of the two compounded Systems are in Ratios compounded of the duplicate Ratios of the Velocities in two corresponding Pipes, and of the simple Ratios of their Diameters and Lengths, that is, $F . f :: V^2 D L . v^2 d l$.

Scholium.

This *Proposition* will hold true, if the two Systems be made of Conical Pipes equal in their Capacities and Lengths to the Cylindrical ones, and so obstructed, as that the greatest or least Diameters of any two corresponding Conical Pipes shall every where bear the same Proportion to each other, as the Diameters of the two Cylindrical Pipes which are equal to them.



PROPOSITION V. Problem I.

THE *Velocity of a given Fluid moving thro' a Cylindrical Pipe of a given Diameter and Length, and the Force generating the Motion, being given; it is required to determine the Velocities generated by an equal Force*

Force in the several Parts of a System like one of those described in the Third Proposition.

The two Forces generating the Motions in the Cylindrical Pipe and in this System being equal by Supposition; their Measures will be so too. For the Force generating the whole Motion in the System, is the Sum of the Forces generating the Motions in all its Parts; and the Measures of the Forces generating the Motions in the several Parts of the System, are in Ratios compounded of the duplicate Ratios of the Velocities in those Parts, and of the simple Ratios of their Lengths and Diameters; by *Cor. 7. Prop. 1.* Wherefore putting L for the Length of the Cylindrical Pipe, D for its Diameter, V for the Velocity of the Fluid moving through it; l for the Length of that Trunk thro' which

which the Fluid flows into the System, d for its Diameter, and x for the Velocity of the Fluid flowing thro' it; Λ for the mean Length of the Branches, Δ for the Diameter of a Cylinder whose Length is that mean Length, and whose Orifice is equal to the Sum of the Orifices of all the Branches; λ for the Length of the other Cylindrical Trunk, and s for its Diameter: the Measure of the Force generating the Motion of the Fluid flowing thro' the Cylindrical Pipe will be $V^2 D L$; and the Measure of the Force generating the Motion in that Trunk which leads into the System will be $x^2 d l$. The mean Velocity in the Branches, is to x the Velocity in that Trunk, as d^2 , is to Δ^2 ; because the Velocities of the same Quantity of Fluid flowing thro' two Cylindrical Pipes in the same Time, are reciprocally proportional to the Squares of their Dia-

Diameters; whence the mean Velocity in the Branches will be $\frac{x d^2}{\Delta^2}$; and the Measure of the Force generating the Motion in the Branches taken all together, will be $\frac{x^2 d^4 \Lambda}{\Delta^3}$: By the same Reasoning the Velocity in the other Trunk thro' which the Fluid flows out of the System, will be $\frac{x d^2}{s^2}$; and the Measure of the Force generating the Motion of the Water flowing through it, will be $\frac{x^2 d^4 \lambda}{s^3}$: But the Sum of the Forces generating the Motions in all the Parts of the System, is by Supposition equal to the Force generating the Motion in the Cylindrical Pipe; and by Consequence, $x^2 d l + \frac{x^2 d^4 \Lambda}{\Delta^3} + \frac{x^2 d^4 \lambda}{s^3} = V^2 D L$; whence x is equal to $\frac{V}{d^2} \sqrt{\frac{D L}{\frac{1}{d^2} + \frac{\Lambda}{\Delta^2} + \frac{\lambda}{s^2}}}$.

If

If this Value of x be substituted in its Room in $\frac{xd^2}{\Delta^2}$, the Measure of the mean Velocity in the Branches; that Measure will become $\frac{V}{\Delta^2}$.

$$\sqrt{\frac{DL}{\frac{1}{d^3} + \frac{\Lambda}{\Delta^3} + \frac{\lambda}{\delta^3}}}$$

If the said Value of x be substituted in its Room in $\frac{xd^2}{\delta^2}$, the Measure of the Velocity in the other Trunk; that Measure will become

$$\frac{V}{\delta^2} \sqrt{\frac{DL}{\frac{1}{d^3} + \frac{\Lambda}{\Delta^3} + \frac{\lambda}{\delta^3}}}$$

Cor. 1. If the Capacity of the Branches be encreased by an Enlargement of their Diameters or an Encrease of their Number, that is, if Δ be encreased, all other Things continuing the same; the Velocities generated by a given Force, will be

be greater in the Trunks and less in the Branches, than they were before this Change happened in the Capacity of the Branches.

Cor. 2. If the Capacity of the Branches be lessened by a Contraction of their Diameters or a Decrease of their Number, that is, if Δ be diminished, all other Things continuing the same; the Velocities generated by a given Force, will be less in the Trunks and greater in the Branches, than they were before this Change was made in the Capacity of the Branches.

Cor. 3. If the two Trunks of the System be given; the Velocities generated by a given Force, will be greatest in the Trunks and least in the Branches, when Δ is infinite; in which Case the Term $\frac{\Lambda}{\Delta^3}$ will vanish

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nish or become nothing: The Velocity in the Trunk, through which the Fluid flows into the System, will

be measured by $\frac{V}{d^2} \sqrt{\frac{DL}{1 + \frac{\lambda}{d^2}}}$: The Ve-

locity in the Branches will be infinitely little: And the Velocity in the other Trunk will be

$$\frac{V}{d^2} \sqrt{\frac{DL}{1 + \frac{\lambda}{d^2}}}.$$

Cor. 4. If the Velocity in the given Cylindrical Pipe be equal to the Velocity in that Trunk thro' which the Fluid flows into the System, that is, if V be equal to x , and consequently V^2 equal to x^2 ; and if the Diameter of the Pipe, be equal to the Diameter of that Trunk, that is, if D be equal to d ; then the Length of the Cylindrical Pipe or L , will be equal to $1 + \frac{d^2 \Delta}{\Delta^2} + \frac{d^2 \lambda}{d^2}$.

Cor.

Cor. 5. If the Branches taken together, be wider than either of the Trunks; the mean Velocity in them will be less than it is in the Trunks: And if one Trunk be wider than the other, the Velocity will be less in Proportion as the Trunk is wider.



Proof by EXPERIMENTS.

THE greater of the two Systems, which were made for the Proof of the *Third Proposition*, was screwed into the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and turned till its Branches were parallel to the Horizon. The Branches of this System were so contrived, that their Ends which were next to the Vessel might be opened or shut by little

Brass Valves or Sliders. This System being thus situated, when the Branch C only was open; the Trunk G discharged $29\frac{1}{2}$ Ounces of Water in half a Minute: When the three Branches b, c, d were open, it discharged 36 Ounces in half a Minute: And when all the five Branches were open, it discharged $36\frac{5}{8}$ Ounces in the same Time. The Velocities in the two equal Trunks, were as the Quantities discharged. When one Branch only was open, the Velocity in that Branch, was equal to the Velocity in the Trunk; and therefore the Velocity in the Branch C, when the rest of the Branches were shut, was as $29\frac{1}{2}$. The mean Velocity in the three Branches, found by applying 36 to 3 the Sum of their Orifices, the Orifice of each of the Trunks being 1, was as 12: and the Velocity in the five Branches, when they were all

all open, found by dividing $36\frac{1}{2}$ by 5, was as $7\frac{13}{40}$. These were the true Velocities in the Trunks and Branches in these three Experiments. I shall now shew what they ought to have been by this Problem.

The two Trunks and Branch G taken together, may be considered as one Cylindrical Pipe; and therefore may represent the given Cylindrical Pipe in this Problem, in which the Velocity V is as $29\frac{1}{2}$. The Trunks and Branches of this System having all equal Diameters, D, d, and λ were equal. The Lengths of the two Trunks were equal, and when added together, their Sum was equal to the Length of the Branches added to the Lengths of the two pyramidal Spaces into which they opened; therefore l was equal to λ , and $l + \lambda$ equal to Λ if the pyramidal Spaces be considered as

Parts

Parts of the Branches, on which Supposition L was equal to $1 + \lambda + \Lambda$; and by Consequence equal to two Feet; and 1 and λ were each half a Foot, and Λ one Foot. The Velocity in the Trunks, d being 1 , will

be expressed by $29\frac{1}{2} \sqrt{\frac{2}{1 + \frac{1}{\Delta^2}}}$; there-

fore when three Branches were open, and by Consequence Δ equal to $\sqrt{3}$, the Velocity ought to have been nearly as 38 : And nearly as 40 , when all five were open, and Δ equal to $\sqrt{5}$.

The Velocities in the Branches, expressed by $\frac{29\frac{1}{2}}{\Delta^2} \sqrt{\frac{2}{1 + \frac{1}{\Delta^2}}}$, ought to have been $12\frac{2}{3}$, when three Branches were open; and 8 , when all five were open. The near Agreement of these Velocities with those from Experiments, shews the Velocities in the Trunks and Branches of this System

to

to be rightly determined by this Problem.



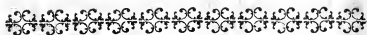
PROPOSITION VI.

I*F a given Fluid flows thro' a simple System of Cylindrical Pipes, consisting of one Trunk and any Number of Branches; the Velocity in any Pipe will be greater or less, according as the moving Force of the System is greater or less, as the Pipe is wider or narrower, shorter or longer, nearer to or farther from the moving Force, as the Weight of Fluid in the Pipe conspires with or opposes its Motion, or as any of the other Pipes of the System is lengthened or shortened.*

That the Velocity in any Pipe of this System is greater or less, as the moving Force of the System is
greater

greater or less, as the Pipe is wider or narrower, shorter or longer, or as the Weight of Fluid contained in the Pipe conspires with or opposes its Motion; has been fully proved in the foregoing *Propositions*. And that the Velocity is greater or less, as the Pipe is nearer to or farther from the moving Force, may be thus proved. From the Nature of this Motion, the whole moving Force is resisted by the Quantity of Fluid contained in the whole System: And that part of this Force which moves the Fluid through any Pipe, is resisted by the Quantity of Fluid in that part of the System which lies before it; the Resistance therefore will be greater or less, as a Pipe is nearer to or farther from the moving Force: But as the Resistance is greater or less, the Pressure of the moving Fluid against the Orifice of the Pipe, and consequently the

the Velocity in the Pipe, is greater or less; and therefore, *ceteris paribus*, the Velocity in a Pipe is greater or less, as it is nearer to or farther from the moving Force. Lastly, the Velocity in a Pipe will be greater or less, *ceteris paribus*, as any of the other Pipes of the System is lengthened or shortened: For by lengthening or shortening a Pipe, the Resistance given by the Fluid contained in it to that part of the moving Force of the System which is spent on that Pipe, becomes greater or less than it was before: But a greater or less Resistance makes the moving Force to act more or less powerfully on the other Pipes, and encreases or lessens the Velocities in them: And therefore the Velocity in a Pipe will be encreased or lessened, *ceteris paribus*, as any of the other Pipes is lengthened or shortened.



Proof by EXPERIMENTS.

THAT the Velocity in a Pipe of this System is greater or less, as the moving Force of the System is greater or less, as the Weight of Fluid contained in it conspires with or opposes its Motion, or as the Pipe is wider or narrower, shorter or longer, is fully proved by the Experiments of the foregoing *Propositions*. And that the Velocity is greater or less, as the Pipe is nearer to or farther from the moving Force, or as any other Pipe of the System is lengthened or shortened, will appear from the following Experiments.

A System of Cylindrical Pipes, consisting of a Trunk, and three
Branches

Branches of equal Diameters and Lengths, all lying in the same Plane; was screw'd into the Side of a Vessel fill'd with Water. The Branches were placed at the Distances of four, nine, and sixteen Feet from that End of the System where the moving Force was apply'd, and beginning with that which lay nearest to the moving Force, they discharged in a given Time Quantities of Water, which were as the Numbers 9, 6, and 5. The Branches having equal Diameters, the Velocities in them were as the Quantities discharged; and therefore, the Velocity in a Pipe will be greater or less, *cæteris paribus*, as the Pipe is nearer to or farther from the moving Force.

A given Branch at the Distance of one Foot from the moving Force discharged 20 Ounces of Water in half a Minute, when the Length of

the Trunk was two Feet; and 36 Ounces in the same Time, when the Length of the Trunk was encreased to eight Feet. And a like Change of Velocity in a less Degree, was produced by lengthening any of the other Branches; and therefore, the Velocity in a given Pipe will be greater or less, *cæteris paribus*, as any of the other Pipes of the System is lengthened or shortened.



PROPOSITION VII.

IF a given Fluid flows thro' a simple System of Cylindrical Pipes, consisting of one Trunk and any Number of Branches; and if any Pipe of the System be obstructed or opened, contracted or dilated, the Velocity will be encreased or diminished in all the other Pipes of the System: And the
Increase

Increase or Diminution of Velocity in any one of them, will be greater or less, cæteris paribus, as the Pipe is nearer to or farther from the obstructed or opened, contracted or dilated Pipe.

Since to obstruct or contract a Pipe, is in Effect to lengthen it; and to open or dilate it, is in Effect to shorten it; the first part of this *Proposition*, is true by the preceding: And the second part of it is thus proved. When a Pipe is obstructed or contracted, that part of the moving Force which before this Change generated the Motion destroyed in the obstructed or contracted Pipe, is not lost, but spent in increasing the Motions in the other Pipes which are open, and may be considered as a new Force apply'd to the System at the Place of Obstruction or Contraction, and propagated from thence to all the
other

other Pipes of the System ; and therefore, by the last *Proposition*, the Velocities generated in those Pipes by this new Force, will be greater or less, as the Pipes are nearer to or farther from the Force, that is, as they are nearer to or farther from the Place of Obstruction or Contraction. And the contrary must happen, when a Pipe is opened or dilated ; the Velocities will then be diminished in all the other Pipes, and the Diminution will be greater or less, *cæteris paribus*, as the Pipes are nearer to or farther from the Place of Aperture or Dilatation : And therefore the *Proposition* is true.

Cor. If the simple System be so constructed, that the Velocities in its Trunk and Branches be respectively equal to the Velocities in that principal and those lesser Trunks of such a compounded System of Cylindrical Pipes, as is described

described in the fourth *Proposition* or its *Scholium*, thro' which Trunks the Fluid flows into the compounded System and lesser Systems of which it is composed; then, whatever Change is made in the Velocities in any two corresponding Pipes of the two Systems, it will produce like Changes of Velocity in all the other corresponding Pipes; and by Consequence, when the Velocity is lessened in any one of the said lesser Trunks of the compounded System, it will be increased in all the others; and its Increase will be greater or less, *cæteris paribus*, as the Trunks are nearer to or farther from that in which the Velocity is lessened: And when the Velocity is increased in one of the said lesser Trunks, it will be lessened in all the rest: And its Diminution will be greater or less, *cæteris paribus*, as they are nearer to or farther from that

Trunk

Trunk in which the Velocity is increased.



Proof by EXPERIMENTS.

A System of Cylindrical Pipes had five Branches, A, B, C, D, E, of equal Diameters and Lengths. The Branch A lay nearest to the moving Force, then B, and so on in the Order they are mentioned. The Velocities in these Branches, obtained from the Quantities of Water discharged in a given Time, were as the Numbers $94\frac{2}{3}$, 68, 52, $36\frac{1}{3}$, $19\frac{1}{7}$, when the End of the Trunk was open; and as the Numbers 98, $76\frac{1}{4}$, $70\frac{1}{2}$, $66\frac{1}{2}$, $61\frac{1}{6}$, when the End of the Trunk was shut; and the Differences of the Velocities in the same Pipes, when the End of the Trunk was open and shut, were $3\frac{1}{3}$,

$3\frac{1}{3}$, $8\frac{1}{4}$, $18\frac{1}{2}$, $30\frac{1}{6}$, $42\frac{1}{42}$. When the Branch C was shut, the Velocities in the Branches A, B, D, E, were as the Numbers $99\frac{1}{2}$, $81\frac{1}{2}$, $43\frac{3}{4}$, $23\frac{1}{3}$; and the Differences between these and the Velocities in the same Branches, when C was open, were $4\frac{5}{6}$, $13\frac{1}{2}$, $7\frac{1}{2}$, $4\frac{1}{3}$. And the same Changes of Velocity, but in a lesser Degree, will be produced when a Pipe is only contracted.

If the System originally had had but the four Branches A, B, D, E, and afterwards the Branch C had been added; it is evident from these Experiments, that the Velocities in the original Branches would all have been diminished by the Addition of this new Branch; and that the Diminution of Velocity in any of them would have been greater or less, as it lay nearer to or farther from the Branch C: But the adding a new Pipe to a System, will produce like

L Changes

Changes of Motion in the other Pipes, as the opening or dilating an old Pipe; for by all these, there will be a like Abatement of the Force generating the Motion in the other Pipes.

Therefore by these Experiments and the *Corollary* of this *Proposition*, when any Pipe of the simple System, or any of the aforesaid Trunks of the compounded System, is obstructed or opened, contracted or dilated; the Velocity will be encreased or diminished in all the other Pipes of the simple System, and all the rest of the aforesaid Trunks in the compounded System; and its Increase or Diminution in any one of those Pipes or Trunks, will be greater or less, *cæteris paribus*, as it is nearer to or farther from the Pipe or Trunk which is obstructed or opened, contracted or dilated.



SECTION II.



*Of Muscular Motion, the Motion of
the Blood, and Respiration.*



Of Muscular Motion.

A Muscle appears to the Eye, to be composed of two Parts of different Colours, one red, and the other white. The red is called its fleshy, and the white its tendinous Part. Some Muscles are tendinous both at their Origin and Insertion, and fleshy only in their Middle; and others are fleshy at their Origin and in their Middle, and tendinous only at their Insertion. The fleshy Part

of a Muscle is composed of Fibres, Membranes, Nerves, Blood-Vessels, and Lympheducts. The Fibres are small Threads, which are shortened when a Muscle is contracted, and lengthened when it is dilated. The Membranes are thin Skins, which run between the Fibres, are fastened to them, and tye them together. If a Piece of Flesh be boiled, till it become very tender, and afterwards be divided and subdivided, as far as the Eye and Hand can go; it will appear, that each minute Fibre in the lowest Subdivision, is intirely surrounded by its own particular Membrane. The Membranes, if they be extremely thin, are transparent; and if they be thicker, they are of a whitish Colour. The Nerves are dispersed throughout the whole fleshy Part, as may be gathered from the Pain which is produced any where in that Part by the smallest Wound.

Wound. It has been a received Opinion, that the Nerves are small Pipes which contain a Fluid, called *Animal Spirits*, drawn off from the Blood in the Brain. But it does not appear from any Experiments, that the Nerves are Pipes; or that such a Fluid as they conceive *Animal Spirits* to be, is separated from the Blood in the Brain; and therefore these Opinions are without any just Foundation. The Nerves are not only impervious to the smallest *Stylus*, but when viewed with a Microscope, evidently appear to have no Cavity. And when we consider the Manner, in which the Favourers of this Opinion have explained *Muscular Motion* by *Animal Spirits*; we must allow, that such a Fluid is altogether unfit for this Work. For these Reasons, many have thought the Nerves to be solid Threads, extended from the Brain to the Muscles
and

and other Parts of the Body. Sir
Isaac Newton is of this Opinion, as
appears from the following Account
he has given of the Nerves, in the
24th *Query* of his *Opticks*. “ I sup-
“ pose that the *Capillamenta* of the
“ Nerves are each of them solid
“ and uniform, that the vibrating
“ Motion of the *Ætherial Medium*
“ may be propagated along them
“ from one End to the other uni-
“ formly, and without Interruption:
“ For Obstructions in the Nerves
“ create Palsies. And that they
“ may be sufficiently uniform, I
“ suppose them to be pellucid when
“ viewed singly, tho’ the Reflecti-
“ ons in their Cylindrical Surfaces
“ may make the whole Nerve
“ (composed of many *Capillamen-*
“ *ta*) appear opaque and white. For
“ Opacity arises from reflecting
“ Surfaces, such as may disturb and
“ interrupt the Motions of this Me-
“ dium.”

“dium.” The Blood-Vessels of a Muscle are interwoven in the Membranes, and distributed throughout its whole fleshy Part, as appears from its Redness, and from the issuing out of Blood from a Puncture made any where in it with the finest Needle. The Muscles are stocked with Lymphatick Vessels, as well as the other Parts of the Body.

Having premised this short Account of the Structure of a Muscle, I now proceed to explain its Motion.



PROPOSITION VIII.

MUSCULAR Motion is performed by the Vibrations of a very Elastick Æther, lodged in the Nerves and Membranes investing the minute Fibres of the Muscles, excited by Heat, the Power of the Will, Wounds, the
subtile

*subtile and active Particles of Bodies;
and other Causes.*

It has been found by Observation, that when a Muscle is contracted, its fleshy Fibres are shortened and hardened, without any sensible Change made in its Tendons; that as soon as the Contraction is over, or the contracting Force ceases to act, the shortened and hardened Fibres are lengthened and softened again; that this alternate Motion of Contraction and Dilatation continues in the Hearts of some Animals, especially young ones, for a considerable Time after they are cut out of their Bodies, and laid on a Table; that it generally continues longer in the Hearts of Fish, than in the Hearts of Land-Animals; and that after it has ceased, it may be renewed again by Warmth or the pricking of a Pin, and will continue

nue

nue to be excited by either, especially Warmth, for a little Time, till the Heart wholly loses its Power of moving; that as the Heart cools by Degrees, so its Motion abates gradually, its Contractions and Dilatations growing less and less frequent and strong, till at last they wholly cease; and that the Heat of the Heart is greater, and its Motion more frequent and strong, in an ardent Fever, and the hot Fit of an Ague, than in its natural State.

Hence it appears, that Heat is a remote Cause both of the Frequency and Strength of the Motion of the Heart; and consequently, one of the remote Causes of the Motion of a Muscle.

We find by Experience, that we can move the Muscles of our Limbs with various Degrees of Force by the sole Power of the Will; that there is not the least sensible Diffe-

M rence

rence in point of Time between willing the Motions of the Muscles, and the Motions themselves; that Muscles contracted by the Power of the Will, dilate again at the very Instant in which the Soul ceaseth to exercise that Power; and that the Soul loseth the Power of moving the Muscles, and perceiving Pain from Wounds made in their fleshy Parts, when their Nerves are cut quite through, tyed streight, or intirely obstructed any other Way.

Hence it appears, that the Nerves are the Instruments whereby the Will gives Motion to the Muscles: And it does this, by producing some kind of Motion in those Ends of the Nerves which terminate in the Brain, which Motion is propagated from thence thro' their solid, pellucid and uniform *Capillamenta* into the Muscles. For if the Nerves were intirely at Rest, and no Motion

tion was propagated through them, they could never by the Power of the Will, or any other Cause, produce Motion in the Muscles.

On laying bare the great Muscle of the hinder Leg of a Dog, and the great Nerve which accompanies the Crural Artery and Vein, I have observed, that when the Tendon was wounded, the Dog shewed very little Uneasiness; but expressed great Pain on wounding the fleshy Part of the Muscle, and much greater Pain, on wounding, or in the Instant of tying the Nerve; that a Contraction of the Muscle was produced, on wounding its fleshy Part, and a much stronger Contraction on wounding, or in the Instant of tying the Nerve; and that after the Nerve was cut quite through, or tyed streight, great Uneasiness and Pain with most violent Struggles were produced, as often as a new Wound was inflicted, or a

new Ligature made, above the last Section or Ligature, in that Part of the Nerve which communicated with the Brain; but that neither Pain nor Contraction of the Muscle followed, on wounding or tying that Part of it which communicated with the Muscle and Limb. And I have likewise observed on trepanning Dogs, and wounding several Parts of their Brains, that convulsive Motions of the Limbs have ever been produced, on wounding the *Medulla oblongata*, but never on wounding the *Dura Mater*, or Cortical Part.

Hence likewise it appears, that the Nerves are the principal Instruments of Sensation and Motion; that these Effects are stronger or weaker, as more or fewer of the nervous *Capillamenta* are tyed or wounded; that these Effects are the same, in whatever Part of a Nerve
the

the Section or Ligature is made; and that the Soul perceives Pain, and exerts its Power of producing *Muscular Motion*, only at the Origin of the Nerves in the Brain.

The exceeding Quickness of this Motion, passing from the Brain thro' the *Capillamenta* of the Nerves to the most distant Muscles in an Instant, and its Cessation the very Moment the Cause which produced it ceases to act, shew it to be the vibrating Motion of a very elastick Fluid. For it is the Nature of the vibrating Motion of an elastick Fluid to be very swift, and to cease when the Cause which produced it ceases to act. A vibrating Motion excited in our Air by the Tremors of Bodies for the Production of Sounds, moves at the Rate of 1142 *English* Feet in a second Minute of Time, and ceases when the Tremors of the Bodies cease.

Now

Now since this Motion begun in the Nerves at their Origin, has been proved to be the vibrating Motion of a very elastick Fluid; and since the other Phænomena of Nature absolutely require such an elastick Fluid, as is the Æther described by Sir *Isaac Newton*; and since Causes are not to be multiply'd without Necessity: Therefore it must be granted, that this Motion begun in the Nerves at their Origin, is the vibrating Motion of that Æther; the Properties of which, gathered from the Phænomena, are these which follow.

This Æther is exceedingly more rare and subtile than Air, and exceedingly more elastick and active. It readily pervades all Bodies, and by its elastick Force is expanded thro' all the Heavens. If it be 700000 times more elastick than our Air, it is above 700000 times more rare. Its
elastick

Rays of Light, the Will of Animals, or other Causes; its Vibrations or Pulses move swifter than Light, and by Consequence, above 700000 times swifter than Sounds. Its Density and expansive Force, are both increased in Proportion to the Strength and Vigour of its vibrating Motion; which Motion, like the vibrating Motion of the Air for the Production of Sounds, grows weaker, as the Square of the Distance from the Place, in which it is excited, increases. And lastly, its vibrating Motion is regularly propagated thro' Bodies made of uniform dense Matter, but is reflected, refracted, interrupted or disordered by any Unevenness in the Bodies.

These are the principal Properties, with which this Æther must necessarily be endued; which I thought fit to mention, before I shew the Manner in which it causes the Motion of the Muscles.

When

When by the Power of the Will a vibrating Motion is excited in the Æther, in those Ends of the Nerves which terminate in the Brain; that Motion is in an Instant propagated thro' their solid and uniform *Capillamenta* to the Membranes of the Muscles, and excites a like Motion in the Æther lodged within those Membranes; and a vibrating Motion raised in the Æther within the Membranes, increases its expansive Force; an Increase of that Force swells the Membranes; a Swelling of the Membranes causes a Contraction of the fleshy Fibres; and that Contraction, a Motion in the Parts to which the Extremities of the Muscles are fastened. Thus the Limbs and other Parts of Animals are moved by their Muscles, each of which has its two Ends fastened to two Bones, whereof one is always more moveable than the o-

N

ther;

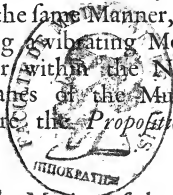
ther ; on which Account, when its fleshy Fibres are shortened by the swelling of the Membranes, the more moveable Bone is drawn towards that which is more fixed, by means of an intervening Joint upon which it turns.

As soon as the Will ceases to act, the vibrating Motion of the Æther caused by that Action ceases ; in like manner as the Pulses of the Air causing Sounds cease, on a Cessation of the Tremors of sonorous Bodies, by which they are excited ; and a Cessation of the vibrating Motion of the Æther, causes a Diminution of its expansive Force ; and a Diminution of that Force, gives an Opportunity to the dilated Membranes to contract, by the attractive Powers of their Parts, and thereby to lengthen the fleshy Fibres. Another Cause of the lengthening of the fleshy Fibres and Dilatation
of

of a Muscle, is a vibrating Motion, excited in the Æther lodged in the fleshy Fibres by their Contraction: For that vibrating Motion will increase the expansive Force of the Æther, and that increased Force will lengthen the Fibres, the very Instant the Cause which contracted them ceases to act. These two Forces added together, make the whole Force whereby a contracted Muscle is dilated: For the Experiments above-mentioned fully prove, that the Soul has no immediate Power over the fleshy Fibres. Thus the Muscles of Animals are moved by the Æther, when put into a vibrating Motion by the Power of the Will.

I have shewn that Heat, Punctures or Wounds, and Ligatures on the Nerves in the Instant they are made, have a Power of contracting the Muscles: And from the Effects of

vomiting and purging Medicines, and some Poisons, we learn, that the subtile and active Particles of some Bodies have a like Power: But since all these Things, however different they are in themselves, do notwithstanding produce the same Effect which the Will does, they must do it in the same Manner, that is, by exciting a vibrating Motion in the Æther within the Nerves and Membranes of the Muscles. And therefore the *Proposition* is true.



Cor. 1. The Motion of the Muscles becomes weak, either from too weak a vibrating Motion of the Æther in their Membranes and Fibres; or an Unfitness in the Membranes and Fibres to be moved with Vigour by a due Degree of that vibrating Motion. The vibrating Motion excited by a given Force.

Force becomes weak, when the *Æther* becomes rare; and the *Æther* becomes rare, when the Membranes and Fibres become dense, from Moisture soaking into their Pores, from Compression, or other Causes. And the Membranes and Fibres become unfit to be moved with Vigour, when they are rendered stiff by Age, too hard Labour, or other Causes.

Cor. 2. Muscles grow larger and stronger by moderate Exercise: For the expansive Force of the *Æther* must be encreased, before it can move the Muscles; and a frequent Increase of this Force in Muscles much moved, must of Necessity increase both their Magnitudes and Strengths. Hence labouring Persons have larger and stronger Muscles, than Persons who lead a sedentary and inactive Life.

Cor.

Cor. 3. The Blood moving thro' a Muscle, is pressed forward by the Force of its Contraction ; but after a Muscle is contracted, if it be kept in that State by the constant Action of the Force which contracted it, less Blood will flow through it in a given Time than did before: For the Blood-Vessels interwoven in the Membranes, are compressed and contracted by the swoln Membranes and shortened and hardened Fibres : And this Contraction of the Vessels, while it is exerting, presses the Blood forward ; but afterwards hinders the Blood from flowing through the Muscle in that Quantity it did before. Hence Exercise performed by the Motion of the Muscles, accelerates the Motion of the Blood ; and Cramps and other permanent Convulsions retard it.

Cor.

Cor. 4. The Magnitude of a Muscle may be but little altered by its Contraction: For if the Contraction of the fleshy Fibres be nearly equal to the Swelling of the Membranes, its Magnitude will continue much the same, though its Figure be changed.

Cor. 5. The Forces of corresponding Muscles in healthful Bodies, are measured by their Weights, and the Strengths of the vibrating Motions of the Æther in them, taken together.

Cor. 6. If a great Increase of the vibrating Motion of the Æther in the Nerves and Membranes of one Part of a Body, be attended with a Diminution of its vibrating Motion in the Nerves and Membranes of other Parts; then it may be in the
Power

Power of Art to quiet a Disturbance in one Part, by raising a stronger Disturbance in another : As by Blisters, Cauteries, and other powerfully stimulating Bodies, applied to one Part of a Human Body, we often relieve Pain, and quiet convulsive Motions in other Parts of it.





Of the Motion of the Blood.



PROPOSITION IX.

THE Blood moves in the Arteries
and Veins with a kind of Circular Motion.

Harvey has proved this from Experiments and Observations: For he has shewn, that the Blood flows out of the Trunk of the *Vena cava*, into the right Auricle of the Heart; out of that, into the right Ventricle; thence, thro' the Lungs, into the left Auricle and Ventricle; out of the left Ventricle, into the *Aorta*; whose Branches convey it to all Parts of the Body, and pour it into

O

the

the smallest Branches of the Veins; out of which it passes into Branches still larger, till at last, by the *Vena cava* it is brought back to the Heart. And this Motion of the Blood from and to the Heart, is called its *Circulation, or Circular Motion*.

The Heart and Arteries act upon the Blood, in generating and keeping up its Motion, in the following Manner. When the Auricles are filled with Blood by the Veins, the right Auricle by the *Vena cava*, and the left by the Pulmonary Vein, they both contract at one and the same Time, and press the Blood which they contain into the Ventricles; and when the Ventricles are filled with Blood, they likewise contract at one and the same Time, and press the Blood which they contain into the Arteries; the right Ventricle into the Pulmonary Artery,

tery, and the left into the *Aorta*. The Arteries are dilated by the Blood, forcibly pressed into them by the Ventricles; and as soon as the Ventricles are emptied, and their Contraction is over, the dilated Arteries contract, and press the Blood forward into the Veins. And thus the Motion of the Blood is generated and kept up, by the Forces of the Heart and Arteries.

The Blood is kept from regurgitating, by the Valves of the Heart and Veins. The Valves at the Entrance of the Auricles into the Ventricles, open when the Auricles contract, and permit the Blood to flow into the Ventricles; and shut when the Ventricles contract, and prevent its Return into the Auricles. The Valves at the Origins of the *Aorta* and Pulmonary Artery, open when the Ventricles contract, and suffer the Blood to flow

into the Arteries; and shut when the Arteries contract, and hinder it from flowing back into the Ventricles. And the Valves of the Veins open to let the Blood move forward towards the Heart; and shut to prevent its Return into the Arteries.

Cor. 1. The two Ventricles of the Heart throw out equal Quantities of Blood in each Systole: For they always contract together; and therefore if they threw out unequal Quantities, more or less Blood would flow into the Lungs, than flows out of them, in a given Time: Which must of Necessity soon put an End to Life.

Cor. 2. As much Blood flows thro' each Ventricle of the Heart, and thro' the Lungs in any Time, as flows thro' all the rest of the Body in that Time.

Cor.

Cor. 3. The Arteries have a Pulse, and the Veins no Pulse: For the Arteries have a stronger muscular Coat than the Veins, on account of their sustaining a greater Pressure against their Sides from the Blood forced into them by each Systole of the Heart; and they sustain a greater Pressure against their Sides than the Veins, from a greater Quantity of Blood lying before them, which gives a greater Resistance to the Blood forced into them by the Heart. Now the Sides of both Arteries and Veins being soft and dilatable, it is evident, that the whole System of Vessels must swell, when Blood is forcibly pressed into it by the Heart in its Systole; and endeavour to contract again, when the Force of the Heart ceases to act in its Diastole: But when the Arteries and Veins begin to contract after every Systole of the Heart, the
Arteries,

Arteries, by the greater Strength of their Muscular Coat, overpower the Veins; and by pressing the Blood into them, hinder them from contracting: Therefore the Arteries by dilating and contracting, have a Pulse; and the Veins for want of this alternate Motion, have no Pulse.



PROPOSITION X.

THE *mean Velocity of the Blood is less in the Sum of the Branches of both Arteries and Veins, than the Velocity in their respective Trunks; and the Velocity is less in the Veins, than in their corresponding Arteries.*

For it has been found by measuring the Vessels, that the Branches of an Artery or Vein taken all together,

gether, are wider than the Trunk out of which they arise; and that the Veins are wider than their corresponding Arteries: And therefore the *Proposition* is true, by the 5th *Corollary* of the 5th *Proposition*.

Cor. 1. Hence it appears, that the Velocity of the Blood is continually lessened in the Arteries from their Trunks to their smallest Branches; and increased continually in the Veins from their smallest Branches to their Trunks: And by Consequence, that the Velocity is least in the last and smallest Branches of the Arteries and Veins.

Cor. 2. Since the Velocity of the Blood is least in the smallest Branches of the Arteries and Veins; it necessarily follows, that the Blood will be more liable to be obstructed by Cold and other Causes, in its Course thro'

thro' those Vessels, than thro' any others.

PROPOSITION XI.

THE *Velocity of the Blood in one and the same Artery or Vein, is the same both in the Systole and Diastole of the Heart; when the Arteries are dilated, and when they are contracted.*

For since the Veins have no Pulse, the Blood must necessarily flow thro' them with the same Velocity when the Arteries are dilated, and when they are contracted; which it could not do, if it moved faster through the Arteries when they are dilated, than when they are contracted; in the Systole of the Heart, than in its Diastole: And therefore the *Proposition* is true.

Cor.

Cor. 1. Hence it appears, that while the progressive Motion of the Blood continues the same; the Force which generates this Motion, must by its constant Action continually generate as much Motion as is destroyed by the Resistance of the internal Surface of the whole System of Blood-Vessels; otherwise it would be impossible, that the Velocities of the Blood in the same Vessels should be the same in the Systole of the Heart, and in its Diastole; when the Arteries are dilated, and when they are contracted.

This will not appear strange when we consider, that there are other Motions in Nature which are uniform, notwithstanding the constant Action of a given moving Force. Of this kind is the Motion of a Ship, generated by a Wind blowing constantly and uniformly; which Motion is at first accelerated,

till as much Motion is continually communicated to the Water and Air by the Ship moving along; as is generated in it by the constant and uniform Action of the Wind: And after that, it continues uniform, notwithstanding the constant Action of the Wind. Of this kind also, is the Motion of a Body descending in Water; which Motion is accelerated, till the Motion communicated to the Water by the descending Body, becomes equal to the Motion generated in the Body by the constant and uniform Action of its Weight in Water; and after that, the Motion continues uniform, notwithstanding the constant Action of this Weight.





PROPOSITION XII.

THE *Velocities of the Blood in the corresponding Blood-Vessels of healthful Bodies situated alike with respect to the Horizon, are in the subduplicate Ratios of the Diameters of those Vessels, that is, $V . v :: \sqrt{D} . \sqrt{d}$.*

For from Anatomy and the Similarity of the corresponding Parts of human Bodies we learn, that their Systems of Blood-Vessels have the same Number of corresponding Vessels; and that corresponding Vessels have like Situations and Capacities, in Bodies situated alike with respect to the Horizon, that is, any two corresponding Vessels are situated alike with respect to the rest of

the Vessels, and their Capacities are as the Capacities of the whole Systems.

The Forces of the Hearts of human Bodies are as their Weights, and as the Strengths of the vibrating Motions of the Æther in their Nerves and Membranes, taken together, by *Cor. 5. Prop. 8.* But the Strengths of the vibrating Motions of the Æther, setting aside the Power of the Soul and other disturbing Causes, are as the Heats of the Hearts; and the Heats of the Hearts, as the Heats of the Blood; and the Heats of the Blood are much the same in all healthful Bodies, as I have found by the Thermometer: And therefore, setting aside the Power of the Soul and other disturbing Causes, the Forces of the Hearts are as their Weights. The Weights of the Hearts of a strong Man and a Child newly born, were

were as 16 and 1; the Diameters of their *Aortas* as 2 and 1; and the Lengths of their Bodies as 4 and 1: Now since the Lengths of corresponding Blood-Vessels are as the Lengths of the Bodies, and the Diameters of corresponding Vessels as the Diameters of the *Aortas* in Bodies situated alike with respect to the Horizon; it is evident from this Instance, that the Weights of the Hearts are as the Capacities of corresponding Vessels, or as the Capacities of the whole Systems, in Bodies situated alike with respect to the Horizon: And therefore the Forces of the Hearts, when they are not disturbed by the Power of the Soul or other Causes, are as the Capacities of corresponding Blood-Vessels, or as the Capacities of the whole Systems in Bodies so situated; and the Forces generating the Motions in corresponding Vessels, are

as the Capacities of those Vessels, and by Consequence, as the whole Forces of their Hearts. Moreover if it be considered, that the System of Blood-Vessels swells or contracts as the Force of the Heart is increased or lessened by the Power of the Soul, Heat or Cold, or other Causes; and on the contrary, that the Force of the Heart is increased or lessened, as the System swells or contracts by Heat or Cold; no Doubt can be made, but that the Forces of the Hearts are ever proportional to the Capacities of their respective Systems of Blood-Vessels; and that the Forces generating the Motions in corresponding Vessels, are as the whole Forces of their Hearts in Bodies situated alike with respect to the Horizon.

And these Things being true, the *Proposition* is true, by the *First Corollary* of the *Fourth Proposition*.

Cor.

Cor. 1. Hence it appears, that the Velocity of the Blood increases continually from the Birth, till Bodies are arrived at their full Lengths; and afterwards, it increases or lessens in the same Bodies, as their Systems of Blood-Vessels swell or contract, either from an Increase or Diminution of the Quantity, or a Diminution or Increase of the Density of the Blood.

Cor. 2. When healthful Bodies are situated alike with respect to the Horizon, and their Hearts are free from the Influences of disturbing Causes; the Velocities of the Blood in corresponding Blood-Vessels, are in Ratios compounded of the subquadruplicate Ratios of the Quantities of Blood contained in their whole Systems of Blood-Vessels directly, and of the subquadruplicate Ratios of the Lengths of the Bodies inversely. For the Heat of the
Blood

Blood is the same in Bodies under these Circumstances, as I have found by the Thermometer, and consequently its Density is given; but the Density of the Blood being given, the Capacities of corresponding Blood-Vessels will be as the Quantities of Blood contained in them, or as the Quantities contained in the whole Systems; therefore, putting Q and q for the Quantities contained in two whole Systems, D and d for the Diameters of any two corresponding Blood-Vessels in those Systems, and L and l for the Lengths of the Bodies, $D^2 L$ will be to $d^2 l$ as Q to q , the Lengths of corresponding Blood-Vessels in different Bodies being as the Lengths of the Bodies themselves: So then \sqrt{D} is to \sqrt{d} as $\sqrt[4]{\frac{Q}{L}}$ to $\sqrt[4]{\frac{q}{l}}$: But by this *Proposition*, $V . v :: \sqrt{D} . \sqrt{d}$: And therefore in Bodies under the
 Cir-

Circumstances mentioned in this

Corollary, $V . v :: \frac{Q^{\frac{1}{4}}}{L^{\frac{1}{4}}} . \frac{q^{\frac{1}{4}}}{l^{\frac{1}{4}}}.$

Cor. 3. If two healthful Bodies of equal Lengths, or one and the same Body at two different Times, be situated alike with respect to the Horizon, and their Hearts be free from the Influences of disturbing Causes; the Velocities of the Blood in any two corresponding Blood-Vessels of the two Bodies, or in any one and the same Blood-Vessel of the same Body at two different Times, will be in the subquadruplicate Ratios of the whole Quantities of Blood contained in the two Bodies, or in the same Body at those different Times, by the last *Corollary*: If $L=1$; then will $V . v :: Q^{\frac{1}{4}} . q^{\frac{1}{4}}.$

That the Velocities of the Blood as they are expressed in this *Corol-*
Q
lary,

lary, may be found out more easily, I have added the following Table: Which in the two Columns under Q, contains different Quantities of Blood; and in the two Columns under V, different Velocities expressed in the biquadrate Roots of those Quantities. For Instance, if the Quantities of Blood in two different Bodies of equal Lengths, or in one and the same Body at two different Times, be as 20 and 18; the Velocities in the corresponding Blood-Vessels of the two Bodies, or in the same Blood-Vessel of the same Body at different Times, will be as the Numbers 21147 and 20598, if the Bodies be under the Circumstances supposed in this *Corollary*.

<u>Q</u>	<u>V</u>	<u>Q</u>	<u>V</u>
1	10000	26	22581
2	11892	27	22795
3	13161	28	23003
4	14142	29	23206
5	14953	30	23403
6	15650	31	23596
7	16266	32	23784
8	16818	33	23968
9	17320	34	24147
10	17783	35	24323
11	18211	36	24495
12	18612	37	24663
13	18988	38	24828
14	19343	39	24990
15	19680	40	25149
16	20000	41	25304
17	20305	42	25457
18	20598	43	25607
19	20878	44	25755
20	21147	45	25900
21	21407	46	26043
22	21657	47	26183
23	21899	48	26321
24	22134	49	26457
25	22361	50	26591

Cor. 4. If the Diameters of corresponding Blood-Vessels be in the subduplicate Ratios of the Lengths of the Bodies; the Velocities in those Vessels will be in the subquadruplicate, and the Capacities of the whole Systems in the duplicate Ratios of the Lengths of the Bodies. If $D . d :: \sqrt{L} . \sqrt{l}$; then will $V . v :: L^{\frac{3}{2}} . l^{\frac{3}{2}}$, and $D^2 L . d^2 l :: L^2 . l^2$.

From the Instance mentioned in the Proof of this *Proposition* it is evident, that these Proportions of the Diameters of corresponding Blood-Vessels, and of the Capacities of the whole Systems, obtain in some Bodies when situated alike with respect to the Horizon; and it is as certain, that they do not obtain in all Bodies so situated; because of Bodies of the same Length, some, from a different Use of the Non-naturals or other Causes, have larger
Blood-

Blood-Vessels than others : Now if these Proportions be observed in the most perfect and best proportioned Bodies, they will likewise obtain in all Bodies of different Lengths, taking those of each Length one with another, when they are situated alike with respect to the Horizon, that is, the mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths so situated, each Mean being taken from a considerable Number of Diameters of corresponding Blood-Vessels of Bodies of the same Length, will be in the subduplicate; and the mean Capacities of the whole Systems in the duplicate Ratios of the Lengths of the Bodies : Otherwise there could be no Regularity, no Uniformity preserved in the Species.

This

Lengths in Inches.	Velocities.	Capacities of the Sys- tems.
72	2913	5184
66	2850	4356
60	2783	3600
54	2711	2916
48	2632	2304
42	2546	1764
36	2449	1296
30	2340	900
24	2214	576
18	2060	324

This Table contains in the first Column, the Lengths of Bodies in Inches; in the second, the true or mean Velocities of the Blood in the corresponding Blood-Vessels of Bodies situated alike with respect to the Horizon; and in the third, the true or mean Capacities of the whole Systems of Blood-Vessels of Bodies of those Lengths. For Instance,

stance, the true or mean Velocities of the Blood in the corresponding Blood-Vessels of Bodies alike situated, whose Lengths are 72 and 36, are as the Numbers 2913 and 2449; and the true or mean Capacities of their whole Systems of Blood-Vessels, as the Numbers 4 and 1.

Cor. 5. If the Diameters of corresponding Blood-Vessels of Bodies situated alike with respect to the Horizon, be as the n Power of the Lengths of the Bodies; the Velocities in those Vessels will be as the $\frac{n}{2}$ Power; and the Capacities of the whole Systems, and Quantities of Blood if the Forces of the Hearts are not disturbed, as the $2n+1$ Power of the Lengths of the Bodies, that is, $V. v :: L^{\frac{n}{2}}. l^{\frac{n}{2}}$, and $D^2 L. d^2 l :: L^{2n+1}. l^{2n+1}$, and $Q. q :: L^{2n+1}. l^{2n+1}$ if $D^2 L. d^2 l :: Q. q$.

For

For Example, If the Diameters of corresponding Vessels be in the subtriplicate Ratios of the Lengths of the Bodies, and the Lengths of the Bodies be 72 and 18 ; the Velocities will be as the Numbers 63 and 50 ; and the Capacities of the Systems and Quantities of Blood, as the Numbers 10 and 1.



PROPOSITION XIII.

THE *Velocities of the Blood in the corresponding Blood-Vessels of healthful Bodies situated alike with respect to the Horizon, are in Ratios compounded of the simple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole directly, and of the duplicate Ratios of the Diameters of those Vessels and of the simple Ratios of the Times*

Times of one Systole inverſly. If K, k denote the Magnitudes of the Quantities of Blood thrown out of the Hearts of two Bodies in one Systole, and T, t the Times of one Systole; I ſay, that

$$V . v :: \frac{K}{D \cdot T} \cdot \frac{k}{d \cdot t}.$$

For the Velocities of the Blood in any two correſponding Blood-Veſſels, are directly as the Spaces deſcribed by the Blood in the Times of one Systole, and inverſly as thoſe Times : But the Spaces deſcribed by the Blood in the Times of one Systole, are as the Magnitudes of the Quantities of Blood which flow into thoſe Veſſels in the Times of one Systole apply'd to the Orifices or Squares of the Diameters of the Veſſels; and the Magnitudes of thoſe Quantities are as the Magnitudes of the Quantities thrown out of their Hearts in one Systole, if the Bodies be ſituated alike with reſpect

to the Horizon : And therefore, the Velocities in the corresponding Blood-Vessels of Bodies so situated, are in Ratios compounded of the simple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole directly, and of the duplicate Ratios of the Diameters of the Vessels and of the simple Ratios of the Times of one Systole inversely : Which was to be proved.

Cor. 1. If the Magnitudes of the Quantities of Blood thrown out of the Hearts of two Bodies in one Systole, be as the Capacities of any two corresponding Blood-Vessels; the Velocities in those Vessels will be as the Lengths of the Bodies directly, and as the Times of one Systole of their Hearts inversely. If $K. k :: D^2 L. d^2 l$; then will $V. v :: \frac{L}{T}. \frac{l}{t}$.

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This *Corollary* obtains in Bodies which are situated alike with respect to the Horizon, and whose Hearts are not influenced by disturbing Causes: For the Hearts of Bodies under these Circumstances, will throw out in each Systole Quantities of Blood whose Magnitudes are equal to the Capacities of their Ventricles; but the Capacities of the Ventricles are as the Magnitudes of the Hearts; and the Magnitudes of the Hearts are as their Weights; (for I have found their Densities to be so nearly equal, that their Differences may be neglected) and the Weights of the Hearts are as their Forces; and their Forces as the Capacities of corresponding Blood-Vessels by the *Proof* of the 12th *Proposition*; and therefore $K.k::D^{\circ}L.d^{\circ}l$.

Cor. 2. The true Times of one Systole of the Hearts of regular and

well-proportioned Bodies of different Lengths, and the mean Times of one Systole of the Hearts of all Bodies of different Lengths, each Mean being taken from a considerable Number of Bodies of the same Length, are, when the Bodies are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes, as the biquadrate Roots of the Cubes of the Lengths of the Bodies, that is, $T. t :: L^{\frac{3}{4}}. l^{\frac{3}{4}}$. For in these Cases, $V. v :: L^{\frac{1}{4}}. l^{\frac{1}{4}}$ by the 4th Corollary of the 12th Proposition, and $V. v :: \frac{L}{T}. \frac{l}{t}$ by the preceding Corollary of this Proposition; and therefore $L^{\frac{1}{4}}. l^{\frac{1}{4}} :: \frac{L}{T}. \frac{l}{t}$; whence $T. t :: L^{\frac{3}{4}}. l^{\frac{3}{4}}$.

PROPOSITION XIV.

THE *Velocities of the Blood in the corresponding Blood-Vessels of healthful Bodies situated alike with respect to the Horizon, are in Ratios compounded, of the simple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole, and of the simple Ratios of the Numbers of their Pulses in a given Time, directly; and of the duplicate Ratios of the Diameters of those Vessels inversely.* If P, p denote the Numbers of Pulses in a given Time of two healthful Bodies situated alike with respect to the Horizon; then will

$$V.v :: \frac{KP}{D^2} \cdot \frac{kp}{d^2}$$

Proof

*Proof by EXPERIMENTS.*

I Took the Pulses in a Minute, and measured the Lengths, of a great Number of Bodies; I took the Pulses when the Bodies were sitting, that they all might be situated alike with respect to the Horizon; and in the Morning before Breakfast, that their Hearts might be as free as possible from the Influences of all disturbing Causes: And when I had got a very large Stock of Observations, I took the Means of the Pulses, each Mean from a considerable Number of Bodies of the same Length; and found those Means to be nearly as the biquadrate Roots of the Cubes of the Lengths of the Bodies inverſly, that is, nearly as the mean Times of a Syſtole of their Hearts inverſly, by *Cor. 2. Prop. 13.*
And

And³⁴ since the mean Numbers of Pulses in a Minute of all Bodies, are the true Numbers of Pulses in a Minute of single Bodies of the same Lengths which are regular and well-proportioned; the Numbers of Pulses in a Minute of regular and well-proportioned Bodies taken singly, will likewise be as the biquadrate Roots of the Cubes of their Lengths, that is, as the Times of a Systole of their Hearts inverfly, by the afore-said *Corollary*. Now since in these Instances, the Numbers of Pulses in a Minute are inverfly as the Times of one Systole, and since there is no apparent Reason why this Proportion should not be universal; I shall therefore conclude, that it is so:

And that in all Bodies, $P. p :: \frac{1}{T}. \frac{1}{t} :$

But by the last *Proposition*, $V. v ::$

$\frac{K}{D^2 T} \cdot \frac{k}{d^2 t} :$ And therefore, $V. v ::$
 $\frac{KP}{D^2} \cdot \frac{kp}{d^2} .$

To

Ages in Years.	Lengths in Inches.	Pulses from Observation.	Pulses by the Theory.
	72	65	65
	68	67	68
	60	72	74
14	55	77	79
12	51	82	84
9	46	90	91
6	42	97	97
3	35	113	112
2	32	120	119
1	28	126	132
$\frac{1}{2}$	25	137	144
0	18	150	184

To shew the near Agreement of the Pulses from Observation with the Pulses by the Theory, I have added this Table; which contains in the first Column, the mean Ages of growing Bodies when they arrive at the Lengths in Inches standing over

over against them in the second Column; in the third Column, the mean Numbers of Pulses in a Minute in the Morning before Breakfast when the Bodies were sitting; and in the fourth Column, the Numbers of Pulses in a Minute supposing them to be inversely as the biquadrate Roots of the Cubes of the Lengths of the Bodies, and making 65 the first Number in the third Column found from Observation, the first Number in this. In making this Table, I neglected Fractions which were not near an Unit, and put an Unit instead of those which were.

It may be observed, that the Number of Pulses from Observation of a Child newly born, falls considerably short of the Number of Pulses by the Theory. The Pulse of a Child newly born can scarcely be perceived. I have often try'd to
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feel it and count its Numbers in a given Time, but never succeeded: Once I reckon'd 150 Beats or more in a Minute in a Child seven or eight Days old. And therefore, though I have made 150 the mean Number, yet I cannot say, that it is the true mean Number; but supposing it to be so, its falling so much short of the Theory, may in some measure be accounted for from the Nature of that Cause which disposes Infants to sleep almost perpetually; which Cause, by weakening the vibrating Motion of the Æther in the Nerves and Membranes of the Heart, must necessarily make the Pulse slower than it otherwise would be.

Cor. 1. The Velocities of the Blood in the corresponding Blood-Vessels of Bodies, which are situated alike with respect to the Horizon, and whose Hearts are free from
the

the Influences of all disturbing Causes, are in Ratios compounded of the Ratios of the Lengths of the Bodies and of the Numbers of their Pulses in a given Time: For in this Case, the Magnitudes of the Quantities of Blood thrown out of the Ventricles of their Hearts in one Systole, are as the Capacities of corresponding Blood-Vessels, that is, $K.k :: D^2 L. d^2 l$; and therefore, $V. v :: LP. lp$.

Cor. 2. The Velocities of the Blood in the corresponding Blood-Vessels of healthful Bodies of equal Lengths, when they are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes, will be as the Numbers of their Pulses in a given Time, by the last *Corollary*; by which, when $L = l$, $V. v :: P. p$. The same Proportion

S 2

will

will obtain in one and the same Body at two different Times, if the Body at those Times be situated alike with respect the Horizon, and its Heart be free from the Influences of all disturbing Causes: For the same System having different Magnitudes at different Times, may be considered as two Systems of equal Lengths.

Cor. 3. The Quantities of Blood, which in a given Time flow thro' the corresponding Blood-Vessels of healthful Bodies situated alike with respect to the Horizon, when their Hearts are free from the Influences of all disturbing Causes, are in Ratios compounded of the Ratios of the Quantities of Blood contained in their whole Systems of Blood-Vessels, and of the Numbers of their Pulses in a given Time. For the Quantities of Blood which flow thro' corresponding Vessels in a given
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ven Time, are as the Squares of the Diameters of the Vessels, and the Velocities of the Blood flowing thro' them, taken together, that is, as $D^2 V$ and $d^2 v$, or as KP and kp , because $V, v :: \frac{KP}{D^2} : \frac{kp}{d^2}$, by this *Proposition*; But $K, k :: Q, q$, the Density of the Blood being given: And therefore, the Quantities of Blood which flow thro' corresponding Blood-Vessels in a given Time, will be as QP and qp .

The Quantities of Blood of a tall strong Man and of a Child newly born, are as the Numbers 16 and 1; and the Numbers of the Man's Pulses in a Minute in the Morning, when he is sitting, is 65 by the foregoing Table; and if the Number of the Child's Pulses in a Minute be 150, as it is there put down; the Quantities of Blood flowing thro' the Lungs of the Man and of the Child

Child in a given Time, will be as the Numbers 104 and 15. According to *Tabor*, each Ventricle of the Heart of the Man can contain 1500 Grains of Blood; and consequently, when the Heart is not influenced by disturbing Causes, will throw out 5850000 Grains in an Hour: And each Ventricle of the Heart of the Child will throw out 843750 Grains in the same Time. Therefore, about 835 and 120 *Averdupois* Pounds of Blood will pass through the Lungs of the Man and of the Child in an Hour.

If the Quantities of Blood of strong well-proportioned Bodies be $\frac{1}{12}$ Part of their Weights, (as they are according to *Gliffon* and *Tabor*) and if the Weights of a tall strong well-proportioned Man and a strong well-proportioned Child newly born, be 168 and $10\frac{1}{2}$ *Averdupois* Pounds; the whole Quantities of
their

their Blood will be 14 Pounds and $\frac{2}{5}$ of a Pound: And consequently, as much Blood as is contained in the Body, will flow $59\frac{1}{2}$ times thro' the Lungs of the Man, and 137 times thro' the Lungs of the Child, in an Hour.

Cor. 4. If Bodies be situated alike with respect to the Horizon, and their Hearts be free from the Influences of all disturbing Causes; the Quantities of Blood which flow through their Lungs or other corresponding Parts in a given Time in Proportion to the whole Quantities of Blood contained in their Bodies, will be as the Numbers of their Pulses in a given Time: For the Quantities of Blood which flow through corresponding Blood-Vessels in a given Time, are as QP and qp , by the last *Corollary*; but $\frac{QP}{Q}$ and $\frac{qp}{q}$, are as P and p .



PROPOSITION XV.

IF Bodies be situated alike with respect to the Horizon; the Diameters of corresponding Blood-Vessels will be proportional to the fifth Roots of the Squares of the Products made by the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole, and the Numbers of their Pulses in a given Time, that is,

$$D.d :: \overline{K P^{\frac{1}{5}}} . \overline{k p^{\frac{1}{5}}} : \text{The Velocities in corresponding Vessels will be as the fifth Roots of the said Products, that is,}$$

$$V.v :: \overline{K P^{\frac{1}{5}}} . \overline{k p^{\frac{1}{5}}} : \text{And the Forces of their Hearts as the fifth Roots of the fourth Powers of them, and as the Lengths of the Bodies taken together, that is,}$$

$$F.f :: \overline{K P^{\frac{1}{5}}} \times L . \overline{k p^{\frac{1}{5}}} \times l.$$

For

For the Forces of the Hearts of Bodies situated alike with respect to the Horizon, are as the Capacities of corresponding Blood-Vessels, by the Proof of the 12th *Proposition*, and the Lengths of corresponding Blood-Vessels are as the Lengths of the Bodies, wherefore $F. f. D^2 L. d^2 l$: And the same Forces by *Cor. 4. Prop. 4.* are in Ratios compounded of the duplicate Ratios of the Velocities, and of the simple Ratios of the Diameters of those Vessels and of the Lengths of the Bodies, that is, $F. f :: V^2 D L. v^2 d l$: But by the 14th *Proposition*, $V^2. v^2. \frac{\overline{K P}^2}{D^4}. \frac{\overline{k p}^2}{d^4}$; and therefore, $F. f :: \frac{\overline{K P}^2 \times L}{D^3}. \frac{\overline{k p}^2 \times l}{d^3}$: And comparing this Proportion of the Forces with the first, we shall have $D^2 L. d^2 l :: \frac{\overline{K P}^2 \times L}{D^3}. \frac{\overline{k p}^2 \times l}{d^3}$; whence $D. d :: \overline{K P}^{\frac{2}{3}}. \overline{k p}^{\frac{2}{3}}$.

Extracting the Square Root of the last Analogy, $\sqrt{D.} \sqrt{d} :: K P^{\frac{1}{2}}. \overline{k p}^{\frac{1}{2}}$: But $V. v :: \sqrt{D.} \sqrt{d}$, by the 12th Proposition: And therefore $V. v :: K P^{\frac{1}{2}}. \overline{k p}^{\frac{1}{2}}$.

And squaring the same Analogy, $D^2. d^2 :: \overline{k p}^{\frac{4}{2}}. \overline{k p}^{\frac{4}{2}}$: But $F. f :: D^2 L. d^2 l$: And therefore, $F. f :: \overline{k p}^{\frac{4}{2}} \times L. \overline{k p}^{\frac{4}{2}} \times l$.

Cor. 1. If two Bodies of equal Lengths, or one and the same Body at two different Times, be situated alike with respect to the Horizon; the Forces of the Hearts of the two Bodies, or of the Heart of the same Body at those Times, will be proportional to the fifth Roots of the fourth Powers of the Products made by the Magnitudes of the Quantities of Blood thrown out in one Systole, and the Numbers of Pulses in

in a given Time. If $L=l$; then will
 $F, f :: \overline{K P^{\frac{4}{3}}}. \overline{k p^{\frac{4}{3}}}.$

Cor. 2. If two Bodies of equal Lengths, or one and the same Body at two different Times, be situated alike with respect to the Horizon; and if the Hearts of the two Bodies, or the Heart of the same Body at those Times, throw out in one Systole Quantities of Blood whose Magnitudes are equal, that is, if $L=l$, and $K=k$: Then, $D. d :: P^{\frac{2}{3}}. p^{\frac{2}{3}}$, and $V. v :: P^{\frac{1}{3}}. p^{\frac{1}{3}}$, and $F. f :: P^{\frac{4}{3}}. p^{\frac{4}{3}}.$

Examples.

Exam. 1. If from some Cause the Pulse of the same Body becomes twice as quick, as it is in the Morning when the Body is sitting, and its Heart is free from the Influences

of all disturbing Causes; and if it becomes greater than under those Circumstances, from the Heart's throwing out its usual Magnitude of Blood in half the Time; that is, if $P. p :: 2. 1$; and $K = k$: Then, by the second *Corollary* of this *Proposition*, D and d will be as the Numbers 13195 and 10000, V and v as the Numbers 11487 and 10000, and F and f as the Numbers 17411 and 10000. This seems to be the Case of a grown Body heated by an *ardent Fever*, or *violent Exercise*, in which the Pulse is greater than it is ordinarily, and beats about twice as fast as it does in the Morning, when the Body is sitting and its Heart is free from the Influences of all disturbing Causes; and therefore, in a Body so heated, the Diameters of the Blood-Vessels will be increased in the Proportion of 13195 to 10000, the Velocity of
the

the Blood in the Proportion of 11487 to 10000, and the Force of the Heart in the Proportion of 17411 to 10000.

Exam. 2. If the Pulse of the same Body be quicker at one Time than at another, in the Proportion of 80 to 70; and if it be greater from the Heart's throwing out its usual Magnitude of Blood in a less Time, that is, if $P. p :: 80. 70$; and $K = k$: Then, by the second *Corollary* of this *Proposition*, D and d will be as the Numbers 10549 and 10000, V and v as the Numbers 10270 and 10000, and F and f as the Numbers 11127 and 10000. The Pulse is quicker and greater in the *Afternoon*, than it is in the *Morning*; and from many Observations, taking one Hour with another of those two Times, it is quicker in grown Bodies one with another, in the Proportion of about 80 to 70: And there-

	Morning.							Afternoon.							Mean	
Hours.	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Pulses of A.	65	67	70	73	71	69	70	77	77	77	77	76	76	74	76	76
Pulses of B.	66	71	72	68	69	67	67	75	81	84	81	79	77	78	79	78

a Minute of two healthful Men A
and

therefore, the Diameters of the Blood-Vessels of the same Body will be greater in the Afternoon than in the Morning, taking one Hour with another, in the Proportion of 10549 to 10000; the Velocities in the Vessels will be greater in the Proportion of 10270 to 10000; and the Force of the Heart greater in the Proportion of 11127 to 10000.

I have added this Table, to shew the Tenour of the Pulse at different Hours of the Day; it contains the Numbers of Pulses in

and B, when sitting, at the several Hours from eight a Clock in the Morning to eleven at Night. These Numbers, are Means drawn from a large Number of Observations; those of A, from the Observations of twelve Weeks; and those of B, from the Observations of three Weeks. A eat his Breakfast between nine and ten, B his before nine; they both dined together at two, at which Meal B eat more plentifully than A; and they eat little or no Supper.

From this Table it appears, that the Pulse is slower in the Morning, than at any other Time of the Day; that it grows something quicker before Breakfast, and a little more so after it; that it grows slower again before Dinner, and quicker immediately after Dinner; and that the Quickness acquired by this Meal, continues for about three or four Hours,

Hours, and then abates a little; and continues in that State, without any considerable Change, in Bodies which eat and drink little at Night, till they go to Rest.

Exam. 3. If from some Cause the Pulse of the same Body becomes quicker than in the Morning, when the Body is sitting and its Heart is free from the Influences of all disturbing Causes, in the Proportion of 2 to 1; and if it becomes smaller, from the Heart's throwing out in each Systole but a fourth Part of the Blood which it throws out in the Morning under the Circumstances now mentioned, that is, if $P. p :: 2. 1$; and $K. k :: 1. 4$: Then, by this *Proposition* and its first *Corollary*, D and d will be as the Numbers 7578 and 10000, V and v as the Numbers 8705 and 10000, and F and f as the Numbers 5743 and 10000. If this be nearly the Case
of

of a grown Body in a *malignant Fever*, the *Cold Fit of an Ague*, *Convulsions*, and some other Diseases; then, when the Body is sitting, the Diameters of corresponding Blood-Vessels will be lessened in the Proportion of 7578 to 10000, the Velocities in those Vessels will be lessened in the Proportion of 8705 to 10000, and the Force of the Heart will be lessened in the Proportion of 5743 to 10000.

Now since in the Cases mentioned in this *Example*, in which the Force of the Heart is lessened, the Skin is much paler and colder than in a natural and healthful State; and is extremely pale and cold in *dead Bodies*, in which the Force of the Heart is wholly destroyed: And on the contrary, since in the Cases mentioned in the *first Example*, in which the Force of the Heart is increased, the Skin is much redder

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and

and warmer than in a natural and healthful State: We may from the Colour and Warmth of the Skin, most certainly judge of the Force of the Heart; and at the same time see, how as that Force gradually lessens, the Compass of the Blood's Motion gradually contracts; till at last, that Force wholly ceasing to act, the Motion wholly ceases, even in the largest Vessels nearest to the Heart.



PROPOSITION XVI.

I*F the Catamenia flow through Foramina in the Sides of the Blood-Vessels of the Uterus into its Cavity, if there be the same Number of corresponding Foramina in the Sides of corresponding Blood-Vessels in all healthful Bodies, if this Discharge continues*

continues a given Number of Days, and during the Time of its Continuance Bodies be situated alike with respect to the Horizon; the Quantities of one Discharge of grown Bodies will be in Ratios compounded of the duplicate and subduplicate Ratios of the Diameters of corresponding Blood-Vessels, that is, putting C, c for the Quantities of one Discharge of two grown Bodies, $C. c :: D^2 \sqrt{D}. d^2 \sqrt{d}.$

For the whole Quantities of Blood discharged by two healthful Bodies in a given Number of Days, will be as the Quantities discharged by any two corresponding *Foramina* in that Time; and the Quantities discharged by two corresponding *Foramina*, will be as the Squares of their Diameters, and as the Velocities wherewith the Blood flows thro' them, taken together: But the Diameters of two correspond-

ing *Foramina* are as the Diameters of two corresponding Blood-Vessels; and the Velocities wherewith the Blood flows thro' the *Foramina*, are as the Velocities wherewith it flows through those Vessels: And therefore, the Quantities discharged by two corresponding *Foramina*, will be as the Squares of the Diameters of two corresponding Blood-Vessels, and as the Blood's Velocities in those Vessels taken together, that is, as $D^2 V$ and $d^2 v$; or as $D^2 \sqrt{D}$ and $d^2 \sqrt{d}$, because $V. v :: \sqrt{D}. \sqrt{d}$, by *Prop.* 12. But the whole Quantities of one Discharge of two healthful Bodies situated alike with respect to the Horizon, are as the Quantities discharged by two corresponding *Foramina*: And therefore $C. c :: D^2 \sqrt{D}. d^2 \sqrt{d}$.

Cor. 1. If this Proposition be true, it is evident that this Discharge, which

which usually begins in these Countries between the Ages of 14 and 16, will continually increase from its first Appearance till the Bodies arrive at their full Growth; for both the *Foramina* grow larger, and the Velocity of the Blood increases, while Bodies are growing: And it will likewise increase, from some of the *Foramina* being naturally smaller than others, on which Account they will necessarily, not all at once, but successively, become large enough to let the Blood pass through them.

Cor. 2. If this *Proposition* be true, this Discharge will begin soonest and be greatest in Bodies which have the largest Blood-Vessels: For it will begin when the *Foramina* are grown large enough to let the red Parts of the Blood (which are its largest Parts) pass thro' them; but they will be soonest large enough
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to do this, in Bodies which have the largest Blood-Vessels: And the Quantities of a Discharge will be greatest, because the *Foramina* are largest, and the Velocity of the Blood is greatest, in such Bodies.

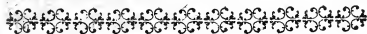
Cor. 3. The Quantities of this Discharge in grown well-proportioned Bodies of different Lengths, and its mean Quantities in all grown Bodies of different Lengths taking those of each Length one with another, will, if this *Proposition* be true, be in Ratios compounded of the simple and the subquadruplicate Ratios of the Lengths of the Bodies; the Diameters of corresponding Blood-Vessels in these Cases, being in the subduplicate Ratios of those Lengths, by *Cor. 4. Prop. 12.*

Cor. 4. Hence it appears, that this Discharge will be increased by
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all Things which swell the Blood-Vessels; and on the contrary, lessened by all Things which contract them: And therefore, it will be increased by whatever increases the Power of the Heart, and heats the Blood; and lessened by whatever lessens the Power of the Heart, and cools the Blood; for the Blood-Vessels swell or contract, as the Force of the Heart is increased or lessened by Heat or Cold, or other Causes.

Cor. 5. Hence it appears, that a Discharge must continue till the Blood-Vessels and *Foramina* are so far contracted by the Loss of Blood, that the *Foramina* are become too small to let the red Parts of the Blood pass thro' them; and then it will cease for that Time, and not return again till the lost Blood be regained, and the Blood-Vessels and
Foramina

Foramina be enlarged to the Dimensions they were of at the coming on of the preceding Discharge; and then another Discharge will begin, continue the same Time, and go off as that did. Thus this Discharge happens once a Month, in which Time the lost Blood is regained; continues in these Countries till about the Age of 50; and then wholly ceases, from the *Foramina* becoming too small to let the Blood pass thro' them. The *Foramina* become too small to let the Blood pass thro' them, from a Rigidity in the Blood-Vessels, which hinders them from being dilated by the Blood as usually: For it appears both from Anatomy and common Experience, that the Blood-Vessels and other solid Parts become more rigid, as Bodies advance in Years.



PROPOSITION XVII.

IF Q denotes the Quantity of Blood contained in a healthful Body before a Discharge of the Catamenia begins, and P and p the Numbers of Pulses in a Minute a little before and after the Discharge, when the Body is sitting, and its Heart is free from the Influences of all disturbing Causes; C , the Quantity of the Discharge, will be $Q \times \frac{P^+ - p^+}{P^+}$.

For the Heart being supposed to be free from the Influences of all disturbing Causes before the Discharge and after it, the Heat and Density of the Blood will be the same before and after; and there-
X fore,

fore, if q denotes the Quantity of Blood contained in the Body after the Discharge is over, $V. v :: Q^{\frac{1}{4}}. q^{\frac{1}{4}}$, by *Cor. 3. Prop. 12*; and $V. v :: P. p$, by *Cor. 2. Prop. 14*; and from these two Analogies, $Q^{\frac{1}{4}}. q^{\frac{1}{4}} :: P. p$; and $Q - q. Q :: P^4 - p^4. P^4$: But $Q - q = C$; and consequently, $C. Q :: P^4 - p^4. P^4$; and $C = \frac{Q \times P^4 - p^4}{P^4}$.

For *Example*, If the Quantity of Blood contained in the Body at the Beginning of the Discharge be 11 *Averdupois* Pounds, and the Pulses in a Minute before and after the Discharge, when the Body is sitting and its Heart is perfectly free from the Influences of all disturbing Causes, be 74 and 73; the Quantity of the Discharge will be above 9 Ounces: If the Quantity of Blood be 11 Pounds, and the Pulses in a Minute

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nute before and after be 74 and 72; the Quantity of the Discharge will be above 18 Ounces.

I have found from Observation, that the Pulse is quicker before the Discharge than after it. The Pulse of a well-proportioned Body 64 Inches high, in which this Discharge was very small, was observed at every Hour of the Day for 8 Months together; and the Pulse of another Body six Inches shorter, in which this Discharge was very great, was observed at every Hour of the Day for a Month; and the mean Numbers of Pulses in a Minute, taken from all the Observations made on the two Bodies in the Week before and Week after the Discharge, were 74 and 72 in the taller Body, and $79\frac{1}{2}$ and 75 in the shorter. The Differences of these Numbers before and after the Discharge, are too great for the Quan-

tity of the Discharge in these Climates; which I believe does not ordinarily exceed 12 Ounces in tall and well-proportioned Bodies. And if from more Observations of the Pulse of perfectly healthful Bodies, which have this Discharge in due Quantities, it shall be found, that the Differences of its Numbers before and after the Discharge make it greater than it really is in these Climates; then the Quantity of a Discharge cannot be determined by this *Proposition*, which supposes the Heart before and after the Discharge to be free from the Influences of all disturbing Causes: But it may be determined by the next *Proposition*, when from Experiments and Observations all the Terms used in it shall be known.





PROPOSITION XVIII.

IF Q denotes the Quantity of Blood contained in the Body at the Beginning of a Discharge of the Catamenia, P and p the Numbers of Pulses in a Minute when the Body is sitting, K and k the Magnitudes of the Quantities of Blood thrown out of the Heart in one Systole, and Δ and δ the Densities of the Blood, just before the Discharge begins and after it is over; C , the Quantity of the Discharge, will be

$$Q \times \frac{\overline{K P^{\frac{4}{3}}} \times \Delta - \overline{k p^{\frac{4}{3}}} \times \delta}{\overline{K P^{\frac{4}{3}}} \times \Delta}.$$

For the Capacities of one and the same Blood-Vessel before and after the Discharge, are as the Squares of its Diameters; which
Squares

Squares, when the Body is sitting, are as $\overline{K P}^{\frac{4}{3}}$ and $\overline{k p}^{\frac{4}{3}}$ by the 15th Proposition: And the Quantities of Blood contained in one and the same Blood-Vessel at those Times are as the Squares of its Diameters and as the Denfities of the Blood taken together: But the Quantities of Blood contained in the whole Body, are as the Quantities contained in one and the same Blood-Vessel when the Body is sitting: And therefore, the Quantities of Blood contained in the whole Body before and after the Discharge, are as $\overline{K P}^{\frac{4}{3}} \times \Delta$ and $\overline{k p}^{\frac{4}{3}} \times \delta$, that is, $Q. q :: \overline{K P}^{\frac{4}{3}} \times \Delta. \overline{k p}^{\frac{4}{3}} \times \delta$; whence $Q - q = C =$

$$Q \times \frac{\overline{K P}^{\frac{4}{3}} \times \Delta - \overline{k p}^{\frac{4}{3}} \times \delta}{\overline{K P}^{\frac{4}{3}} \times \Delta}.$$

Cor. 1. If the Degrees of Heat in the Blood, and consequently its Denfities,

Densities, before and after the Discharge, be equal; and if the Magnitudes of the Quantities thrown out in one Systole before and after be likewise equal, that is, if $\Delta = \delta$, and $K = k$; then will $C = Q \times \frac{P^{\frac{4}{3}} - p^{\frac{4}{3}}}{P^{\frac{4}{3}}}$.

For *Example*, If the Quantity of Blood contained in the Body when the Discharge begins be 11 Pounds, and the Numbers of Pulses in a Minute before and after the Discharge when the Body is sitting be 74 and 70; the Quantity of the Discharge will be above $7\frac{1}{2}$ Ounces; and near 9 Ounces, if the Quantity of Blood in the Body when the Discharge begins be 12 Pounds. The Degrees of Heat in the Blood before and after the Discharge, may be known by a Thermometer truly adjusted: And by the Fulness of the Pulse we may judge of the Magnitudes of
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the Quantities of Blood thrown out in one Systole : And therefore, from Experiments and Observations carefully made by Persons who have an Opportunity of doing it, the Quantity of a Discharge may be nearly known by this *Proposition*.



PROPOSITION XIX. Problem II.

THE *Blood-Vessels of a particular Part of the Body being obstructed or opened, contracted or dilated; to determine the Changes made in the Velocities of the Blood, and in the Magnitudes of the Blood-Vessels, of all the other Parts.*

Case I. If the Arterial Trunk of a Part be obstructed or contracted, so as either wholly or in some Degree to hinder the Blood from flowing

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ing thro' that Part; the Velocity will be increased in all the other Parts, and its Increase will be greater or less, *cæteris paribus*, as the Arterial Trunks of those Parts are nearer to or farther from the Trunk which is obstructed or contracted, by *Cor. Prop. 7.*

The Blood-Vessels of the Part, whose Artery is obstructed or contracted, will contract and grow less, from a Destruction or Diminution of the Force of the Blood's Motion, which before the Obstruction or Contraction of the Trunk kept those Vessels distended: And the Blood-Vessels of all the other Parts will swell or grow larger, by the Force of the augmented Motion of the Blood in those Parts; and their Swelling or Enlargement will be greater or less, *cæteris paribus*, as they are nearer to or farther from the obstructed or contracted Trunk.

Like Changes will be made in the Velocities of the Blood and in the Magnitudes of the Blood-Vessels of all the other Parts, if, instead of the Arterial Trunk of a Part, any of the Branches of that Part (whether Arteries or Veins) be obstructed or contracted; because such Obstruction or Contraction will lessen the Velocity in the Arterial Trunk, by *Cor. 2. Prop. 5*; and by Consequence, will produce like Changes in the Velocities and Magnitudes of the Vessels of the other Parts, as would be produced by a real Contraction of that Trunk.

Case II. If the Arterial Trunk of a Part be opened or dilated, the Blood will flow faster into that Trunk and slower through all the other Parts of the Body than it did before; and the Diminution of Velocity in the other Parts will be greater

greater or less, *cæteris paribus*, as they are nearer to or farther from the Trunk which is opened or dilated, by *Cor. Prop. 7.*

If the Trunk be opened, and the greatest part of the Blood, which flows into it, flow out of the Orifice; the Vessels of that Part will contract and grow less, from the Blood running out of them, and their not receiving their usual Supply to keep them distended. And the Vessels of all the other Parts will likewise be contracted, from a Diminution of the Velocity of the Blood in them; and their Contraction will be greater or less, *cæteris paribus*, as they are nearer to or farther from the Trunk which is opened; and they will undergo like Changes of Magnitude, when the Arterial Trunk is only dilated; tho' the Vessels of the Part supply'd by the dilated Trunk will all swell and grow larger,

larger, contrary to what happened to them when the Trunk was opened. Like Changes will be made in the Velocities of the Blood, and in the Magnitudes of the Vessels of other Parts, when instead of the Arterial Trunk, one or more of the Branches (whether Veins or Arteries) of a Part are opened or dilated. For a Dilatation or Opening of any of the Branches will increase the Velocity in the Arterial Trunk, by *Cor. 1. Prop. 5* ; and by Consequence, will produce like Changes in the Velocities of the Blood, and the Magnitudes of the Vessels of the other Parts as would be produced by a real Dilatation or Opening of the Arterial Trunk.

Case III. If the Venal Trunk of a Part be obstructed or contracted, the Blood will thereby be either totally or in some Degree hindered from
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from flowing out of the Part; on which Account, more Blood will flow in for some little Time than flows out; and by Consequence the Vessels will swell till they can be no farther distended. After that, if less Blood flows into the Arterial Trunk of the Part than did before, like Changes of Velocity and Magnitude will be produced in the Blood-Vessels of all the other Parts, as were produced in them by the Obstruction or Contraction of the Arterial Trunk by the *first Case*.

Case IV. If the Venal Trunk of a Part be opened or dilated, the Blood will flow faster thro' the Part than it did before; because the Aperture or Dilatation either takes off or lessens the Resistance arising from the Blood which lies before it: The Velocity therefore will be increased in the Arterial Trunk, and lessened
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in the Vessels of all the other Parts; and its Diminution in those Vessels, and the Contraction of their Magnitudes consequent thereon, will be greater or less, *cæteris paribus*, as the Vessels are nearer to or farther from the Part whose Vein is opened or dilated, by the *second Case*. The Vessels of the Part, whose Venal Trunk is opened, will contract, notwithstanding the Velocity of the Blood in them is increased: For by the Aperture, the Resistance given by the Blood lying beyond it to the Motion of the Blood through the Part, will be taken off; and by Consequence, the Velocity of the Blood flowing through the Part will be increased: But this Increase of Velocity beginning in the Vein at the Place of Aperture, and thence successively running through the Venal and Arterial Branches, and at last ending in the Arterial Trunk,

Trunk, it is evident, that more Blood will in a given Time flow out of each of these Vessels, that flows in; and by Consequence, all these Vessels will be contracted; and the Contraction will first begin, where the Increase of Velocity first began, and successively go through the Vessels in the same Manner as that did.

Cor. 1. Hence it appears, that if a Part be overloaded with Blood, it will be soonest emptied by opening the Vessels of the Part it self; and next, by opening the Vessels of the Parts which are nearest to it.

Cor. 2. If the Blood flows too fast into some one Part, from an Aper-
ture or Dilatation of some of its
Blood - Vessels; the preternatural
Influx of Blood into that Part will
be lessened by increasing the Mo-
tion

tion of the Blood thro' the other Parts.

Cor. 3. If the Blood flows too flow into some one Part, from an Obstruction or Contraction of some of its Blood-Vessels; the Motion through this Part will be increased by contracting the Vessels and lessening the Motion thro' the other Parts.

N. B. There may perhaps be some little Disturbances given to these Laws of Apertures and Obstructions, Dilatations and Contractions of the Blood-Vessels, from several Inosculations of Arteries with Arteries, and Veins with Veins; but as these Disturbances cannot be accurately determined, so neither can they be considerable; as appears from the Success of Practice grounded on these Laws.

PROPOSITION XX. Problem III.

TO determine the Changes made in the Velocities of the Blood and Magnitudes of the Blood-Vessels in different Parts of the Body; when it is situated differently with respect to the Horizon.

The corresponding Arteries and Veins are every where contiguous; and the Veins are larger than their corresponding Arteries, and consequently, contain a greater Quantity of Blood: On which Accounts, when the Force of Gravity in a Vein conspires with or opposes the Motion of the Blood through it, that Motion will be more increased or lessened by the Force of Gravity in the Vein, than it is lessened or in-

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creased

creased by the same Force in the corresponding Artery; and more or less Blood will by virtue of this Force flow through the Vein, than will flow through the Artery in the same Time; and therefore, if the Vein and Artery be the two Trunks of a Part; more or less Blood will flow out of the Part than flows in, and, in Consequence thereof, the Blood-Vessels of the Part will be contracted or dilated. For Instance, in the Day when the Body is erect, Gravity conspires with the Motion of the Blood from the Head, and opposes its Motion from the Legs; and in the Night, when the Body is horizontal, Gravity neither conspires with or opposes the Motion from these Parts: And hence the Head will contain less, and the Legs more Blood, in the Day than in the Night.

PROPOSITION XXI. Problem IV.

TO determine the Influence and Power of the Soul over the Motion of the Heart.

That the Soul has a very great Power over the Heart, appears from the following Instances. A dying Man, who had had little or no Pulse, and had been in cold clammy Sweats for several Hours, was by an Accident exceedingly alarmed, and thrown into the greatest Disturbance of Mind; upon which his Heart and Blood gradually recovered their Motions to a considerable Degree, and kept them above an Hour, till his Mind grew calm and easy; and then they lost them again, and he died in less than half

an Hour. A strong Extension of the Legs and Arms by the Power of the Will, has quickened the Pulse 20 Beats in a Minute, and at the same Time made it so low, that it could scarcely be felt. The Pulses in a Minute of a Man lying, sitting, standing, walking at the Rate of two Miles in an Hour, at the Rate of four Miles in an Hour, and running as fast as he could, were 64, 68, 78, 100, 140, and 150 or more. When a Body stands up, the Pulse begins to grow quicker the very Instant the Body begins to rise, or the Soul begins to exercise the Power which raises it; and when a Body moves, it grows still quicker; and the Soul exercises more Force to move the Body, in Proportion to the Quickness of the Motion: When a Body first stands up and begins to move, the Pulse is smaller than it was before; but grows greater.

greater by Degrees, as the Body grows warm by the Motion. A Fit of Laughter has quickened the Pulse 25 Beats in a Minute: And breathing voluntarily three or four Times faster than usually, has quickened it 13 or 14 Beats: The Pulse is quickened by coughing, swallowing, reading loud, or by any Motion that is performed by the Power of the Soul. From hence it appears, that the Motion of the Heart is changed mediately or immediately, by every Change made in the Affections, Activity or Power of the Soul.





Of Respiration.



PROPOSITION XXII.

IF an heated Body be placed in a Wind blowing uniformly; the Time of its cooling will be greater or less, as the Quantity of Matter in the Body, or its Degree of Heat at the Time of its being first placed in the Wind, or the Degree of Heat in the Wind, is greater or less; or as the Surface of the Body is less or greater.

For if the Degree of Heat in the Body at the Time of its being first placed in the Wind, and the Degree of Heat in the Wind, be both given; the Time of its cooling will be

be as the Quantity of Heat in the Body in Proportion to the Measure according to which it is cooled: But the Degree of Heat in the Body being given, its Quantity of Heat will be as its Quantity of Matter; and the Surface of the Body is the Measure according to which it is cooled: And therefore, the Time of cooling will be as the Quantity of Matter in the Body in Proportion to its Surface; and by Consequence, will be greater or less, as the Quantity of Matter is greater or less, or as the Surface is less or greater: If the Body, and Degree of Heat in the Wind, be both given; the Time of its cooling will be greater or less, as the Degree of Heat in the Body, when first placed in the Wind, is greater or less. From Sir *Isaac Newton's Scale of the Degrees of Heat*, it appears, that the Time of the Body's cooling will not be
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proportional to its Heat when first placed in the Wind: For if one and the same Body has different Degrees of Heat, the Times of its cooling will be in Arithmetick Proportion, when the Degrees of Heat are in Geometrick Progression; whence the Time of cooling in Proportion to the Heat, will for the most part be greater when the Heat is less; and therefore, the Time of cooling will not be proportional to the Degree of Heat in the Body when first placed in the Wind; and yet it will ever be greater when the Heat is greater, and less when it is less: If the Body, and its Degree of Heat when first placed in the Wind, be both given; the Time of cooling will be greater or less, as the Wind is warmer or colder, that is, as the Degree of Heat in the Wind is less or greater: And therefore, the *Proposition* is true.

Cor. 1. If a Body of a given Figure be heated to a given Degree, and then placed in a Wind blowing uniformly, and the Degree of Heat in the Wind be given; the Time of its cooling, will be as a given Side and Density of the Body taken together, as is evident from the Proof of this *Proposition*. If the Body be a Cube, the Time of its cooling will be as the Side and Density of the Cube; and if a Globe, as the Diameter and Density of the Globe; taken together.

Cor. 2. If a homogeneous Body of a given Figure be heated to a given Degree, and then placed in a Wind blowing uniformly whose Heat is given; the Time of its cooling will be as a given Side of the Body. If the Body be a Cube, the Time of its cooling will be as the Side of the Cube; and if a Globe, as its Diameter.



PROPOSITION XXIII.

IF an heated Body be placed in a Wind blowing uniformly; the Heat which it loses in a very short given Time, when first placed in the Wind will be as the Heat and Surface of the Body taken together directly, and as the Heat of the Air inversely. If S denotes the Surface of the Body, H its Degree of Heat when placed in the Wind, A the Degree of Heat in the Wind, and h the Heat that is communicated to the Air and lost in the Body in a very short given Time; then h will be as $\frac{SH}{A}$.

For the Air heated by the Body will be constantly carried off by the Wind, and other Air will succeed
into

into its Place with an uniform Motion; by which Means, equal Parts of Air will be heated by the heated Body in equal Times, and conceive a Heat proportional to the Heat of the Body; and consequently, one and the same heated Body, placed in a Wind blowing uniformly whose Degree of Heat is given, will when first placed in the Wind communicate to the Air, and consequently lose, in a short given Time, a Heat which is proportional to the Heat of the Body: If the Body be different, but its Degree of Heat, and the Degree of Heat in the Wind, be both given; the Body will communicate to the Air, and consequently lose, in a very short given Time, a Heat which is proportional to the Surface of the Body: And if both the Body and its Degree of Heat be given; it will communicate to the Air, and consequently lose, in a

very short given Time, a Heat which is proportional to the Coldness of the Wind; which Coldness is inverfly as its Degree of Heat: And therefore, the Heat communicated to the Air, and lost by a Body heated and placed in a Wind blowing uniformly, will be as the Heat and Surface of the Body taken together directly; and as the Heat of the Wind inverfly, that is, h will be as $\frac{SH}{A}$.

Cor. 1. If the Heat of the Wind be given; the Heat which is communicated to the Air, and lost in the Body, in a given Time, will be as the Surface of the Body, and as its Degree of Heat when first exposed to the Wind, taken together. If A be given, h will be as SH .

Cor. 2. If the Degree of Heat in the Body, when first exposed to the Wind,

Wind, be given; the Heat communicated to the Air, and lost in the Body, in a given Time, will be as the Surface of the Body directly, and as the Degree of Heat in the Wind inverſly. If H be given, h will be as $\frac{S}{A}$.

Cor. 3. If the Surface of the Body be given; the Heat which is communicated to the Air, and lost in the Body, in a given Time, will be as the Heat of the Body, when firſt expoſed to the Wind, directly; and as the Heat of the Wind inverſly. If S be given, h will be as $\frac{H}{A}$.

Cor. 4. If the Degree of Heat in one and the ſame Body, or in different Bodies of which the Surfaces are equal, be given, when firſt expoſed to the Wind; the Heat which the Body or Bodies will communicate

cate to the Air, and consequently lose, in a very short given Time, will be inverfly as the Heat, or directly as the Coldness of the Wind.

If S and H be given, h will be as $\frac{I}{A}$.



PROPOSITION XXIV.

THE *Life of Animals is preserved by acid Parts of the Air, mixing with the Blood in the Lungs: Which Parts dissolve or attenuate the Blood, and preserve its Heat; and by both these, keep up the Motion of the Heart.*

I shall prove the Truth of this *Proposition*, from a Series of Experiments and Observations.

First then, Animals die, when they are deprived of Air by stopping

ping the Wind-pipe, or putting them in an Air Pump and drawing out the Air. And they likewise die soon in a small Quantity of Air so closely confined, as to have no Communication with the rest of the Atmosphere: Small Birds cannot live above three or four Hours in a Quart of such Air; and a Gallon of Air included in a Bladder, and by a Pipe alternately inspired and expired by the Lungs of a Man, will become unfit to preserve Life in little more than one Minute of Time.

Hence it appears, that Air is necessary to preserve the Life of Animals: And likewise, that a constant Supply of fresh Air is necessary to that End.

Secondly, A Candle goes out, glowing Coals, and red-hot Iron cease to shine, and Animals die, in the

the Air-Pump on drawing out the Air. A Candle goes out, glowing Coals and red-hot Iron cease to shine, and Animals die, in a small Quantity of Air so closely confined, as to have no Communication with the rest of the Atmosphere. Animals die in Air rendered effete by burning Coals or Candles in it till they are extinguished, and glowing Coals or Candles are extinguished in Air rendered effete by Animals breathing in it till they die. *Hook* found, that if Air rendered effete be blown on live Coals, it produces no other Effect, than to blow off the Ashes and put out the Fire; and that the more you blow, the more dead is the Light, and the sooner is the Fire quite extinct; insomuch that in a very little Time, the Coals become perfectly black without emitting the least Glimpse of Light or Shining: At which Time, if one
Blast

Blast of fresh Air be blown upon those seemingly dead, extinct, and black Coals, they all begin to glow, burn, and shine afresh, as if they had not been at all extinct; and the more fresh Air is blown upon them, the more they shine, and the sooner are they burnt out and consumed: And Animals put into such effete Air soon die, tho' for some Time they breath, and move their Lungs as before. The Medium found in Damps, is present Death to those who breath it; and in an Instant, extinguishes the brightest Flame, the Shining of glowing Coals, or red-hot Iron, when put into it. Common Air, by passing thro' red-hot Brass, red-hot Iron, red-hot Charcoal, or the Flame of Spirit of Wine, becomes unfit to preserve Life, and the Shining of Fire and Flame.

Hence it appears, that fresh Air preserves Life in Animals by the very same Power, or by the Operation of the very same Parts, whereby it preserves Fire and Flame in sulphureous and unctuous Substances, when once they are kindled.

Thirdly, If two Parts of compound Spirit of Nitre be poured on one Part of Oil of Cloves or Caraway Seeds, or of any ponderous Oil of Vegetable or Animal Substances, or Oil of Turpentine thickened with a little Balsam of Sulphur; the Liquors grow so very hot in mixing, as presently to send up a burning Flame: If a Drachm of the same compound Spirit be poured upon half a Drachm of Oil of Caraway Seeds, even *in vacuo*, the Mixture immediately makes a Flash like Gunpowder: And well-rectified Spirit of Wine poured on the same compound

compound Spirit flashes. Common Sulphur and Nitre powdered, mixed together, and kindled, will continue to burn under Water, or *in vacuo*, as well as in the open Air.

Now since Air is necessary to preserve common Fire and Flame in sulphureous and unctuous Substances, when once they are kindled; and it appears by these Experiments, that Fire and Flame may both be produced and preserved in sulphureous and unctuous Substances, by acid Particles even without Air; it follows, that Air preserves Fire and Flame by means of acid Particles: And since it preserves the Life of Animals, by the Operation of the very same Particles whereby it preserves Fire and Flame; it likewise follows, that it preserves the Life of Animals by its acid Particles.

Fourthly, The Venal Blood is of a deep purple Colour, and the Arterial Blood of a bright red, in all Parts of the Body except the Lungs; and in them the Blood is of a dark purple Colour in the Pulmonary Artery, and of a bright red in the Pulmonary Vein. Hence it follows, that the Blood changes its deep purple Colour into a bright red, in the communicant Branches of the Pulmonary Artery and Vein which are spread on the Vesicles; and that it changes its bright red into a deep purple Colour, in the communicant Branches of the Arteries and Veins of other Parts. If Blood be drawn out of a Vein, its Surface, which is contiguous to the Air, will acquire the same bright red Colour which the Blood acquires in the Lungs; and if this red Surface be cut off with a sharp Knife, the blackish Surface

Surface of the remaining Blood, being now touched and acted upon by the Air in the same Manner as the first, will acquire the same Colour as that did; and the same Change of Colour will be made in the Bottom of the Cake, if it be turned upwards in the Cup, and exposed to the Air; and if Blood just drawn be stirred and agitated, till the Air be intimately mixed with it throughout, its whole Substance will soon acquire the bright red Colour of Arterial Blood. If the Wind-pipe be stopped with a Cork, and some Time after the Operation (when the Air which is shut up in the Lungs is made effete, that is, deprived of its acid Parts) Blood be drawn from the Cervical Artery, it will have the same dark purple Colour as Venal Blood.

Now since from these Experiments, the Air must touch Venal Blood

Blood drawn out of the Body to change its deep purple Colour into a bright red, and the acid Parts of the Air cause the same Change of Colour in the Blood in the Lungs; it will follow, that there must be a like Contact of these acid Parts with the Blood in the Lungs. And since I have shewn, that Air preserves the Life of Animals by its acid Parts; it will likewise follow, that the Life of Animals is preserved by acid Parts of the Air mixing with the Blood in the Lungs.

Fifthly, The bright red Colour acquired by the Blood in the Lungs, from its Purity and Intenseness, is the Red of the second Order of Colours in the Table of Sir *Isaac Newton's Opticks*, p. 206: But the blackish or deep purple Colour of Venal Blood turns into this bright Red, without passing through the Colours

lours of Blue, Green, Yellow, and Orange; and therefore, must arise from the Indigo and Purple of the third Order, and not from the Indigo and Violet of the second: And consequently by that Table, the tinging Corpuscles of the Blood are lessened in the Lungs.

Hence it appears, that the acid Parts of the Air dissolve or attenuate the Blood in the Lungs.

Oil of Vitriol and Water poured successively into the same Vessel, grow very hot in the mixing. *Aqua fortis*, or Spirit of Vitriol, poured upon Filings of Iron, dissolves the Filings with a great Heat and Ebullition. And the Acid of the Air constantly apply'd to sulphureous and unctuous Substances, when once they are kindled, continues to dissolve them with the Heat of Fire and Flame.

From

From these Experiments we learn, that it is the Nature of Acids to dissolve Bodies with Heat; and therefore, since I have shewn that the Acid of the Air dissolves the Blood; it must be allowed, that it warms the Blood at the same time it dissolves it.

When Animals are deprived of the Acid of the Air, the Pulse in less than one Minute of Time becomes small and quick; as may be observed in a Dog, when his Lungs are made flaccid and without Motion by laying open his Thorax. Upon emptying my Lungs of Air as much as I could, and then stopping my Breath; my Pulse has grown small and quick, with a kind of trembling convulsive Motion, in less than half a Minute of Time. And *Thruston* observed the Pulse to grow smaller on an Intermission of Respiration,

piration, and greater again on repeating it.

Hence it appears, that the Motion of the Heart lessens immediately on Animals being deprived of the Acid of the Air; and consequently, that this Acid by dissolving or attenuating the Blood and preserving its Heat, keeps up the Motion of the Heart.

Therefore the *Proposition* is true.

SCHOLIUM.

1. The Motion of the Lungs in breathing is no otherwise necessary to the Life of Animals, than as by this Motion the Lungs receive a constant Supply of fresh Air.

For *Hook*, after he had laid open the Thorax of a Dog, cut away his Ribs and Diaphragm, and taken off the Pericardium, kept him alive before the *Royal Society* of London

above an Hour, by blowing fresh Air into his Lungs with a pair of Bellows. It was observed, that as often as he left off blowing, and suffered the Lungs to subside and lie still, the Dog presently fell into dying convulsive Motions, and soon recovered again on renewing the Blast. After he had done this several Times with like Success, he pricked all the outer Coat of the Lungs with the slender Point of a sharp Penknife, and by a constant Blast made with a double pair of Bellows, he kept the Lungs always distended and without Motion; and it was observed, that while the Lungs were thus kept distended with a constant Supply of fresh Air, the Dog lay still, his Eyes were quick, and his Heart beat regularly; but that upon leaving off blowing, and suffering the Lungs to subside and lie still, the Dog presently fell into dying
ing

ing convulsive Motions, and as soon recovered again on renewing the Blast, and supplying the Lungs with fresh Air.

2. The Motion of the Lungs in breathing does not change the Colour of the Blood in that Part.

For *Lower*, on opening the Pulmonary Vein of a Dog near the left Auricle of the Heart, when his Lungs were kept distended and without Motion by a constant Supply of fresh Air, observed the Blood drawn to have the same florid Colour, as the Arterial Blood of other Parts.

Farther, If the Motion of the Lungs changes the Colour of the Blood from a dark Purple to a bright Red; I see no Reason, why the Motion of the Muscles when continued for some Time should not keep up that red Colour in the Veins; and consequently, why under strong Exercise Venal Blood (contrary to

Experience) should not be of a bright red Colour. For a strong and vigorous Motion of the Muscles must undoubtedly contribute as much to preserve the bright red Colour of Arterial Blood, as the Motion of the Lungs contributes to produce it.

3. The Death of Animals and Extinction of Flame in a confined Air, are not caused by a Diminution of its Elasticity.

For there is sometimes as great a Diminution of Elasticity in the Air in violent Storms of Wind and Hurricanes, as there is in a small Quantity of confined Air at the Time when Animals die and Candles go out in it; and yet no such Effects follow. Farther, If Animals die and Candles go out in a confined Air, from a Diminution of its Elasticity; then these Effects would not be produced in different Quantities of confined Air, until its Elasticity was

was equally diminished in them; But it has been found by Experiments, that at the Time when Animals die and Candles go out in two different Quantities of confined Air, there is a greater Diminution of Elasticity in the smaller Quantity than in the greater: And therefore, Life and Flame are not destroyed by a Diminution of the Elasticity of the Air. This is farther confirmed from an Experiment mentioned above; For if effete Air, however forcibly blown on live Coals, extinguishes them in like Manner as it does when in a State of Rest; then the same effete Air, which in a quiescent State cannot preserve Life, will not be able to do it when it is pressed into the Lungs with any Force, even a greater than is sufficient to swell the Air-Vessels to their usual Magnitudes: And therefore Animals do not die in a confined Air,
from

from the *Vesiculæ* not being sufficiently dilated on account of a Diminution of the Elasticity of the Air. A Diminution of the Elasticity of the Air is no otherwise hurtful, than as it hinders the Vesicles from being sufficiently dilated, and thereby hinders the Blood from receiving its usual Quantity of Acid in a given Time: On which account, the Blood will not be sufficiently dissolved and warmed in the Lungs; which will make Respiration quick and uneasy, but cannot cause sudden Death,

PROPOSITION XXV.

I*f* *healthful Bodies be cloathed alike, and placed in a Wind blowing uniformly, or move gently along in a calm and still Air with the same uniform Motion;*

Motion; and if Heat be generated in their Blood by the Acid of the Air, as fast as it is lost by being communicated to the Air in their Lungs and at their Skins: The Heats generated in their Blood in a short given Time, will be as the Sums of the internal Surfaces of their Systems of Air-Vessels and external Surfaces of their Bodies, and as the Degrees of Heat in their Blood, taken together, directly; and as the Degrees of Heat in the Wind or calm Air inversely. If S, s denote the Sums of the said Surfaces of two healthful Bodies; H, h the Degrees of Heat in their Blood when they are first plac'd in the Wind, or begin to move in a calm and still Air; A, a the Degrees of Heat in the Wind or Air; and G, g the Heats generated in their Blood by the Acid of the Air in a short given Time: I say, that

$$G. g :: \frac{SH}{A} \cdot \frac{sh}{a}.$$

For

For since the Bodies are supposed to be cloathed alike, the external Surfaces of their Bodies will be alike exposed to the Air; and the internal Surfaces of their Systems of Air-Vessels are always alike exposed to it, on account of Respiration; and since it is the same thing to move gently along in a calm and still Air with an uniform Motion, as to stand still in a Wind blowing with the same uniform Motion: It is evident, by the 23^d *Proposition*, that the Heats communicated to the Air and lost in the Blood of healthful Bodies in a very short given Time, will be as the Sums of the internal Surfaces of their Systems of Air-Vessels and external Surfaces of their Bodies, and as the Degrees of Heat in their Blood, taken together directly; and the Degrees of Heat in the Wind or Air inversly: But by Supposition, the Heat is generated by the Acid of
the

the Air as fast as it is lost by being communicated to the Air in the Lungs and at the Skin: And therefore, the Heats generated by the Acid of the Air in the Blood of healthful Bodies in a short given Time, will be as the Sums of the internal Surfaces of their Systems of Air-Vessels and external Surfaces of their Bodies, and the Degrees of Heat in their Blood, taken together, directly; and as the Degrees of Heat in the Wind or Air, inverfly; that is, $G. g :: \frac{SH}{A} \cdot \frac{sh}{a}$.

Cor. i. If the Degrees of Heat in the Blood of Bodies under the Circumstances supposed in this *Proposition*, and the Degrees of Heat in the Wind or calm Air be respectively equal; the Heats generated in the Blood by the Acid of the Air in a given Time, will be as the Sums
D d
of

of the internal Surfaces of the Systems of Air-Vessels and external Surfaces of the Bodies. If $H=h$, and $A=a$; then will $G. g :: S. s$.

From some Experiments made with a Thermometer at the same Time and in the same Place, I have found the Heats of the warmest Parts of the Skin, and consequently the Heats of the Blood, to be nearly equal in healthful Bodies of all Ages, notwithstanding the Limbs of old Bodies are considerably colder than the Limbs of young Bodies, or Bodies of a middle Age: And if by a larger Experience, this shall be found to be universally true; then will this *Corollary* obtain in all healthful Bodies in the same Place and at the same Time: And as these Experiments were made when the Bodies were at Rest, and the Air still and calm, so this *Corollary* will likewise

likewise obtain nearly in Bodies at Rest in a calm and still Air, in the same Place and at the same Time: And granting this, and supposing the external Surfaces of the Bodies to be proportional to the whole internal Surfaces of their Systems of Air-Vessels, and those whole Surfaces to be proportional to the internal Surfaces of all their Vesicles through which the Acid of the Air passes into their Blood; then will the Heats generated in a short given Time in the Blood of healthful Bodies, in the same Place and at the same Time, be as the internal Surfaces of all the Vesicles of their respective Systems of Air-Vessels: And if the Vesicles attract the acid Parts of the Air in Proportion to the Magnitudes of their internal Surfaces, (as I have shewn the Blood-Vessels to act on the Blood by attractive or some other Powers, in Proportion

to the Magnitudes of their internal Surfaces) then will the Heats generated in the Blood by the Acid of the Air in a short given Time, be as the attractive Powers of all the Vesicles.

Cor. 2. If the Degrees of Heat in the Blood of Bodies under the Circumstances supposed in this *Proposition*, be equal; the Heats generated in it by the Acid of the Air in a short given Time, will be, as the Sums of the internal Surfaces of the Systems of Air-Vessels and external Surfaces of the Bodies, directly, and as the Degrees of Heat in the Wind or calm Air, inverfly: If $H=h$, then will $G. g :: \frac{S}{A} : \frac{s}{a}$.

If by the *Thermometer* it shall be found, that the Degree of Heat in the Blood of healthful Bodies is much

much the same at all Seasons of the Year, and in all Climates; then by this *Corollary*, more or less Heat will be generated in the Blood of the same Body in a given Time, as the Air is colder or hotter; which cannot be, unless the Air when it is cold abounds more with this Acid, than when it is hot: And that it does so, appears from Fire burning best when the Air is coldest, and worst when it is hottest. Now if the Air be cooled by the same Acid which generates Heat in the Blood when mixed with it; then as the Air abounds more or less with this Acid, it will be colder or hotter; and more or less Heat will be both generated and lost in the Blood, in a given Time.

By the 24th *Proposition*, the Acid of the Air dissolves or attenuates the Blood, at the same Time it generates Heat in it; and the Dissolution or Attenuation will be greater

or

or less, as more or less of this Acid is mixed with the Blood in a given Time: And therefore the Blood will be more dissolved or attenuated in Winter than in Summer, in cold Countries than in hot. And if the Want of a sufficient Dissolution or Attenuation of the Blood be the Cause of *Malignant Diseases*; Bodies will be more subject to such Diseases in Summer and hot Countries, than in Winter and cold Countries.

This is the general Law of the Attenuation of the Blood, and Heat generated in it, in a given Time, on Supposition that the Degree of Heat in the Blood is given: However, it may sometimes happen, that the Attenuation of the Blood and the Heat generated in it, may not be proportional to the Degree of Coldness in the Air. For the Air may be so excessively cold, and so greatly

ly saturated with this Acid, that the mutual Attraction of its Particles, arising from their Closeness to one another, may hinder them from being drawn into the Blood in as great a Quantity, as when the Air abounds less with them: And whenever this happens, the Fluidity and Heat of the Blood will be destroyed faster than they are generated; and if this continues for any Time, it must of Necessity put an End to Life. The Case here is much the same as in Oil of Vitriol, and some other Acids; which from their too great Strength will not dissolve Metals so quickly, nor raise so great a Heat, as the same Acids when made weaker.





PROPOSITION XXVI.

IF *healthful Bodies, situated alike; whose Hearts and Lungs are free from the Influences of all disturbing Causes, have the mean Capacities of their Systems of Air-Vessels proportional to the mean Capacities of their Systems of Blood-Vessels, and the mean Numbers of their Inspirations in a given Time proportional to the mean Numbers of their Pulses in that Time; the mean Quantities of fresh Air inspired, will be as the mean Quantities of Blood which flow thro' their Lungs in the given Time.*

Since by Supposition, the Bodies are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes; the mean Capacities of the Systems of Blood-Vessels will be as
the

the mean Capacities of corresponding Vessels, that is, as the Squares of their mean Diameters into their Lengths, or into the Lengths of the Bodies; therefore, the mean Capacities of the Systems of Blood-Vessels of Bodies of two different Lengths, will be as $D^2 L$ and $d^2 l$, D and d denoting the mean Diameters of any two corresponding Vessels, and L and l the Lengths of the Bodies: Since likewise by Supposition, the mean Capacities of the Systems of Air-Vessels are as the mean Capacities of the Systems of Blood-Vessels; the mean Capacities of the Systems of Air-Vessels of Bodies of two different Lengths, will be as $D^2 L$ and $d^2 l$, when the Bodies are sitting, and their Hearts free from the Influences of all disturbing Causes: And since also by Supposition, the mean Numbers of Inspirations are as the mean Numbers of Pulses

in a given Time; the mean Quantities of fresh Air inspired by healthful Bodies of two different Lengths, will be as the mean Capacities of their Systems of Air-Vessels, and mean Numbers of their Pulses in that Time, taken together, that is, as D^2LP and d^2lp , P and p denoting the mean Numbers of Pulses in the given Time: But by the *first Corollary* of the 14th Proposition, $P.p :: \frac{V}{L} \cdot \frac{v}{l}$: And therefore, the Quantities of fresh Air inspired in a given Time will be as D^2V and d^2v , that is, as the mean Quantities of Blood which flow thro' the Lungs in the given Time.

The mean Numbers of Pulses and Inspirations in a Minute, of healthful Bodies of three different Lengths in the Morning when they were sitting, were 65, 72, 116, and 17,
19,

19, 30. Hence it appears, that the mean Numbers of Pulses and Inspirations in a given Time, are proportional to one another in healthful Bodies, when they are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes: And if from Experiments it shall be found, that the mean Capacities of the Systems of Air-Vessels are proportional to the mean Capacities of the Systems of Blood-Vessels; then will this *Proposition* be true in healthful Bodies.

Cor. 1. If this *Proposition* be true; the mean Quantities of fresh Air inspired in a given Time by healthful Bodies, will be in Ratios compounded of the duplicate and subduplicate Ratios of the mean Diameters of corresponding Blood-Vessels, that is, as $D^2 \sqrt{D}$ and $d^2 \sqrt{d}$.

E c 2

For

For $V. v :: \sqrt{D}. \sqrt{d}$, by the *Twelfth Proposition*: But the Quantities of fresh Air inspired in a given Time, are as $D^2 V$ and $d^2 v$, by this *Proposition*: And therefore, the Quantities of fresh Air inspired in a given Time will be as $D^2 \sqrt{D}$ and $d^2 \sqrt{d}$.

Cor. 2. If this *Proposition* be true; the mean Quantities of Air inspired in a given Time by healthful Bodies of different Lengths, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies, that is, as $L \times L^{\frac{1}{4}}$ and $l \times l^{\frac{1}{4}}$. For $D. d :: L^{\frac{1}{2}}. l^{\frac{1}{2}}$, by *Cor. 4. Prop. 12*; and by Consequence, $D^2 \sqrt{D}. d^2 \sqrt{d} :: L \times L^{\frac{1}{4}}. l \times l^{\frac{1}{4}}$: But the mean Quantities are as $D^2 \sqrt{D}$ and $d^2 \sqrt{d}$, by the last *Corollary*: And therefore, they will be as $L \times L^{\frac{1}{4}}$ and $l \times l^{\frac{1}{4}}$.

Cor. 3. If this *Proposition* be true; the mean Quantities of Air inspired in a given Time by healthful Bodies of different Lengths, will be in Ratios compounded of the duplicate Ratios of their Lengths, and of the simple Ratios of the Numbers of their Pulses in a given Time, that is, as $L^2 P$ and $l^2 p$. For by this *Proposition*, the mean Quantities of Air inspired in a given Time are as $D^2 V$ and $d^2 v$: But by *Cor. 4. Prop. 12*, $D^2. d^2 :: L. l$, and by *Cor. 1. Prop. 14*, $V. v :: L P. l p$: And therefore, the mean Quantities of Air inspired in a given Time will be as $L^2 P$ and $l^2 p$.

Cor. 4. If this *Proposition* be true; the Quantities of fresh Air inspired in a given Time in Proportion to the whole Quantities of Blood, will
be

be as the Numbers of Pulses in a given Time. For $\frac{V}{L} \cdot \frac{v}{l} :: P. p$, by

Cor. 1. Prop. 14: But $\frac{V}{L} \cdot \frac{v}{l} :: \frac{D^2 V}{D^2 L} \cdot \frac{d^2 v}{d^2 l}$;

And therefore, $\frac{D^2 V}{D^2 L} \cdot \frac{d^2 v}{d^2 l} :: P. p$.





SECTION III.

Of Digestion and Nutrition, Secretion, and the Discharges of Human Bodies.



Of Digestion and Nutrition.



PROPOSITION XXVII.

THE Nourishment of Animals changes its Texture in their Bodies, till it becomes like their solid and durable Parts.

For the solid and durable Parts of Animal Bodies grow out of their
Nou-

Nourishment: But their Growth is from an Addition and Adhesion of like Parts: And therefore, the Nourishment of Animals changes its Texture in their Bodies till it becomes like their solid and durable Parts.

Cor. 1. Hence it appears, that Animals will not be rightly nourished, when their Nourishment does not change its Texture in their Bodies till it becomes like their solid and durable Parts.

Cor. 2. Hence it appears, that the Nourishment, by changing its Texture in the Bodies of Animals, becomes more dry and earthy than it was before; otherwise, it would not be like their solid and durable Parts.

PROPOSITION XXVIII.

THE Texture of the Nourishment
is changed in the Bodies of Ani-
mals, by a gentle Heat and Motion.

The first remarkable Change in the Texture of the Nourishment is made in the Stomach: In this Bowel the solid Parts of the Food are dissolved and intimately mixed with the Fluids. This Mixture is usually called *Chyle*.

Some, from observing that Fluids have a Power of dissolving Bodies, have thought that a Fluid in the Stomach dissolves the Food and turns it into Chyle: But as it does not appear from Experiments and Observations, that there is a Fluid in the Stomach endued with such a Power;

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this

this Opinion is without Foundation.

Others, from observing the great Strength of the Gizzards of Fowls, and that there is commonly Gravel found in them, have imagined, that the Food is dissolved in the Stomachs of Fowls, and consequently in the Stomachs of all Animals, by Attrition or Grinding. But if this Opinion be examined, it will likewise appear to be without Foundation. For the Food of Fowls is mostly Grain, all Sorts of which are hard and covered with tough Skins; and therefore, before this Food can be dissolved and turned into Chyle, it must be softened, and its Skins ground off; the first of which is done by Warmth and Moisture in the Crop, and the second by Attrition in the Gizzard. By these Contrivances, the Food of Fowl is prepared and fitted for Digestion;

gestion; as human Food is by Cookery and other Ways of preparing it, and by the grinding of the Teeth. But if we should grant, that the Food of Fowl is dissolved and turned into Chyle by Attrition; it will by no means follow, that Food is so dissolved and turned into Chyle in a human Stomach, which has no Gravel in it, and has but very little Muscular Strength in Comparison of the Gizzards of Fowls. There may be many different Contrivances in different Species of Animals, to soften, grossly divide, and prepare their Food for Digestion; but it will not from thence follow, that their Food is digested or turned into Chyle by different Causes.

The Food is dissolved and turned into Chyle by a gentle Heat and Motion. Heat makes many Bodies fluid, which are not fluid in Cold.

Lead is melted by a Heat eight times as great as the external Heat of a human Body ; Tin, by a Heat six times as great ; Wax, by a Heat twice as great ; and Bones, with the Addition of a little Water, are dissolved in a Digester by Heat in a little Time. If the Heat of the Stomach be nearly equal to that of the Blood, it may be sufficient, when the Orifices of the Stomach are pretty exactly closed, to dissolve the Food in a few Hours, and turn it into Chyle ; especially when it is assisted by the Motion of the Stomach, which by agitating and mixing the Food will contribute to this End. For since Heat can dissolve solid Bodies, and nothing is found in a human Stomach, besides a gentle Heat and Motion, which can dissolve the Food and turn it into Chyle ; it will follow, that the Food
is

is digested or dissolved, and turned into Chyle, by a gentle Heat and Motion.

The Chyle in moving through the Intestines is farther dissolved by Heat and Motion : And the finest Part of this Fluid being conveyed into the Blood, is still farther changed by the same Causes, namely a gentle Heat and Motion, till it puts on the Form of Blood, and, at last, becomes fit to nourish the Body, by being made like its solid and durable Parts. The Growth of the Chicken in the Shell out of the White of the Egg, is a strong Proof of the Truth of this: For here is manifestly nothing, besides a gentle Heat and Motion, to change the White of the Egg, so as to convert it into Blood, and render it fit Nourishment for all the Parts of an Animal Body.

Cor. Hence Animals will not be rightly nourished, when the Texture of their Food is not rightly changed in their Bodies by Heat and Motion; which may be owing, either to an Unfitness in the Food for such a Change, or to Degrees of Heat and Motion unfit to effect it.



PROPOSITION XXIX.

THE constituent solid Parts of Animals, according to their several Natures, are endued with peculiar attractive Powers of certain Magnitudes or Strengths; by which they draw out of the Fluids moving thro' them like Parts in certain Quantities, and thereby preserve their Forms and just Magnitudes.

For

For without attractive Powers agreeable to their Natures, the constituent solid Parts of Animals cannot draw like Particles out of the Fluids moving through them; and consequently, cannot preserve their Forms: And unless these Powers be of certain Strengths, they cannot draw those Parts in such Quantities as are proper to preserve their Magnitudes: And therefore, the *Proposition* is true.

Cor. 1. Hence Bodies will not be rightly nourished by proper Food changed by just Degrees of Heat and Motion, when the attractive Powers of their solid Parts are changed, either in their Natures or in their Magnitudes.

Cor. 2. Hence Animals of the same Species will grow faster or slower, out of the same Nourishment

ment rightly changed by Heat and Motion; as the attractive Powers of their solid Parts are stronger or weaker. And universally, their Growth in a given Time will be greater or less; as the attractive Powers of corresponding Parts are greater or less; or as the Fluids moving thro' those Parts abound more or less with similar Particles, that is, with Particles rightly fitted to be attracted by those Powers.

General SCHOLIUM.

I have shewn that the Nourishment of Animals becomes more dry and earthy in their Bodies, and that this Change is effected by a gentle Heat and Motion. How a gentle Heat and Motion cause this Change in the Nourishment, may be understood from what Sir *Isaac Newton* has delivered concerning the Nature of Salt. This great Man, find-
ing

ing from Experiments and Observations, that Salts are dry Earth and watry Acid united by Attraction, and that the Earth will not become a Salt without so much Acid as makes it dissolvable in Water, has given the following Account of the Formation of Particles of Salt.

“ As Gravity makes the Sea flow
 “ round the denser and weightier
 “ Parts of the Globe of the Earth,
 “ so the Attraction may make the
 “ watry Acid flow round the den-
 “ ser and compacter Particles of
 “ Earth for composing the Par-
 “ ticles of Salt. For otherwise the
 “ Acid would not do the Office of
 “ a Medium between the Earth and
 “ common Water, for making Salts
 “ dissolvable in Water; nor would
 “ *Salt of Tartar* readily draw off
 “ the Acid from dissolved Metals,
 “ nor Metals the Acid from *Mer-*
 “ *cury*. Now as in the great Globe
 G g “ of

“ of the Earth and Sea, the densest
“ Bodies by their Gravity sink down
“ in Water, and always endeavour
“ to go towards the Center of the
“ Globe; so in Particles of Salt,
“ the densest Matter may always
“ endeavour to approach the Cen-
“ ter of the Particle: So that a Par-
“ ticle of Salt may be compared to
“ a Chaos; being dense, hard, dry,
“ and earthy in the Center; and
“ rare, soft, moist, and watry in
“ the Circumference. And hence
“ it seems to be that Salts are of a
“ lasting Nature, being scarce de-
“ stroy'd, unless by drawing away
“ their watry Parts by Violence, or
“ by letting them soak into the
“ Pores of the Central Earth by a
“ gentle Heat in Putrefaction, until
“ the Earth be dissolved by the Wa-
“ ter, and separated into smaller
“ Particles, which by reason of
“ their Smallness make the rotten
“ Com-

“ Compound appear of a black
 “ Colour. Hence also it may be
 “ that the Parts of Animals and
 “ Vegetables preserve their several
 “ Forms, and assimilate their Nou-
 “ rishment; the soft and moist
 “ Nourishment easily changing its
 “ Texture by a gentle Heat and
 “ Motion, till it becomes like the
 “ dense, hard, dry, and durable
 “ Earth in the Center of each Par-
 “ ticle, But when the Nourish-
 “ ment grows unfit to be assimi-
 “ lated, or the Central Earth grows
 “ too feeble to assimilate it, the
 “ Motion ends in Confusion, Pu-
 “ trefaction and Death.” *Newt.*
Opt. p. 361, 362.

Hence it appears, that to render
 the saline Part of the Aliment fit to
 nourish the solid Parts of Animals
 and Vegetables, part of the super-
 ficial watry Acid must by Heat and
 Motion be drawn off from the Par-

ticles of Salt; by which they will become more dense, hard, dry and earthy, like the solid and durable Parts of the Bodies. And, according to the different Degrees of Heat and Motion in the different Species of Animals and Vegetables, the watry Moisture will be drawn off in different Proportions, so as in each Species to render the Particles like the solid Parts of the Bodies of that Species.

And farther, if we consider that Water is a very fluid tasteless Salt, and that Animals and Vegetables, with their several Parts, grow out of Water and watry Tinctures and Salts; we may from what has been said understand the Manner in which the Nourishment of Animals and Vegetables is changed by a gentle Heat and Motion, till it becomes like the solid and durable Parts of their respective Bodies.

Of

Of Secretion.

PROPOSITION XXX.

THE Glands in the Bodies of Animals, according to their several Natures and Dispositions, are endued with peculiar attractive Powers by which they suck in various Juices from the Blood.

That the Glands of Animals have such attractive Powers, I shall prove from Experiments and Observations.

“ If two plane polished Plates of
 “ Glass (suppose two Pieces of a
 “ polished Looking-Glass) be laid
 “ together, so that their Sides be
 “ parallel and at a very small Distance from one another, and
 “ then their lower Edges be dipped
 “ into

“ into Water, the Water will rise
“ up between them. And the less
“ the Distance of the Glasses is, the
“ greater will be the Height to which
“ the Water will rise. If the Di-
“ stance be about the hundredth
“ part of an Inch, the Water will
“ rise to the Height of about an
“ Inch; and if the Distance be
“ greater or less in any Proportion,
“ the Height will be reciprocally
“ proportional to the Distance very
“ nearly. The Weight of the
“ Water drawn up being the same,
“ whether the Distance between
“ the Glasses be greater or less; the
“ Force which raises the Water and
“ suspends it must be likewise the
“ same, and suffer no Change by
“ changing the Distance of the
“ Glasses. And in like Manner,
“ Water ascends between two Mar-
“ bles polished plane, when their
“ polished Sides are parallel and at
“ a

“ a very little Distance from one
 “ another. And if slender Pipes
 “ of Glafs be dipped at one End
 “ into ftagnating Water, the Wa-
 “ ter will rife up within the Pipe,
 “ and the Height to which it riles
 “ will be reciprocally proportional
 “ to the Diameter of the Cavity of
 “ the Pipe, and will equal the Height
 “ to which it riles between two
 “ Planes of Glafs, if the Semidia-
 “ meter of the Cavity of the Pipe
 “ be equal to the Distance between
 “ the Planes, or thereabouts. And
 “ thefe Experiments fucceed after
 “ the fame Manner *in vacuo* as in
 “ the open Air, (as hath been try’d
 “ before the *Royal Society*,) and
 “ therefore are not influenced by
 “ the Weight or Prefsure of the At-
 “ mosphere.” See *Newt. Opt. p.*
 366, 367.

Now fince the Rife and Sufpen-
 fion of Water between two Glafs
 Planes

Planes and in small Glass Pipes, are not owing to the Pressure of the Atmosphere; they must be caused by an attractive Power in the Glass, proportional to the Weight of Water sustained by it. Let H, h denote the Heights of the Column of Water sustained between the two Glass Planes and of the Cylinder sustained in a small Glass Pipe; B, p the Breadth of the Column and Periphery of the Cylinder; and D, d the Thickness of the Column and Diameter of the Cylinder: And then the attractive Power which sustains the Column will be as HBD , or as B , because H is as $\frac{1}{D}$; and the attractive Power which sustains the Cylinder, will be as $\frac{hpd}{4}$, or as $\frac{p}{4}$, or as p , because h is as $\frac{1}{d}$.

Hence it appears, that the attractive Power which sustains the
 Water

Water arises only from those Parts of the Glass which are contiguous to the Surface of the elevated Water; or more truly, from the Parts of a narrow Surface of the Glass, whose lower Edge touches the Surface of the Water, and whose Height is the small given Distance to which the attractive Power, with which Glass attracts Water, reaches; and therefore, the attractive Powers of the Glass Planes and small Glass Pipe will be as $2B$ and p . But the Powers are as the Weights sustained by them, that is, $2B. p :: HBD. \frac{hpd}{4}$: Whence HD will be equal to $\frac{hd}{2}$; and, when D is equal to $\frac{d}{2}$, H will be equal to h .

This Power varies in one and the same Pipe, or becomes different when exercised on different Fluids. For one and the same small Glass Pipe

H	h	will
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will sustain different Weights of different Fluids, as appears from this Table.

Fluids.	Heights in Inches.	Densities.	Weights.
Oil of Vitriol	1. 1	17245	18969
Water p. 6. Sal Gem p. $\frac{3}{4}$	1. 73	10921	18893
Water p. 6. Sal Gem p. $\frac{1}{2}$	1. 72	10642	18304
Water p. 8. Common Salt p. $\frac{1}{2}$	1. 67	10447	17446
Water p. 6. Salt-perre p. $\frac{1}{2}$	1. 71	10447	17864
Spirit of Vitriol	1. 63	11860	19331
German Spa-Water	1. 75	10111	17694
Common Water cold	1. 75	10000	17500
Common Water boiling hot	1. 64	9781	16040
Good Blood	1. 64	10400	17056
Serum of good Blood	1. 65	10300	16995
Serum in a Dropsy	1. 65	10171	16782
Urine	1. 60	10270	16432
Saliva	1. 54	10100	15554
Milk of a Cow	1. 42	10279	14596
Gall of an Ox	1. 2	10335	12402
Small Beer	1. 44	10111	14559
Cyder	1. 3	10111	13144
Vinegar	1. 23	10279	12643
Common Ale	1. 2	10300	12360
Red Wine	1. 15	9930	11419
Punch	1. 12	10055	11261
Oil Olive	1. 14	9130	10408
Oil of Turpentine	o. 81	9244	7487
Sal Volatile Oleosum	o. 84	8774	7370
Brandy	o. 75	9320	6990
Spirit of Wine rectified	o. 73	8324	6076
Spirit of Harts-horn	1. 44	9802	14114

In the first Column are the Names of the Fluids, in the second the Heights to which they rose in one and the same Glass Pipe, in the third the Densities of the Fluids, and in the fourth the Weights sustained by the same Pipe. I obtained the Weights by multiplying the Heights into the Densities. For the Weights of Cylinders are as their Magnitudes and Densities taken together, or as their Heights and Densities taken together if their Bases be equal: But the Bases of all the Cylinders of different Fluids sustained by one and the same Pipe are equal: And therefore, the Weights of such Cylinders are as their Heights and Densities taken together.

Hence it appears, that one and the same Glass Pipe attracts different Fluids with different Degrees of Force. It attracts Spirit of Vitriol more strongly than Oil of Vitriol,

Oil of Vitriol more strongly than Water impregnated with Salt, Water impregnated with Sal Gem and Nitre more strongly than common Water cold, common Water cold more strongly than the Animal Fluids and common Water made boiling hot, the Animal Fluids more strongly than fermented Liquors, fermented Liquors more strongly than Oils, and Oils more strongly than ardent Spirits.

So then, if equal Quantities of all the Fluids of this Table were mixed together, the same Glass Pipe would suck in different Parts of this heterogeneous Fluid in different Proportions. It would suck in more Parts of Water impregnated with Salt than of Oil or ardent Spirits. The Parts least attracted would be driven off, to make way for those which are most attracted to enter into the Pipe; as in a Fluid
where

where the Force of Gravity alone takes place, the lighter Bodies are forced to ascend, to make way for the Descent of Bodies which are heavier.

Sir *Isaac Newton* has proved from Experiments, that the Particles of Light attract ardent Spirits and Oil more strongly than Water : And by Consequence, if we suppose a small Pipe to be formed out of Particles whose attracting Powers are the same with those of the Particles of Light, and one End of it to be dipped into a heterogeneous Fluid composed of equal Quantities of all the Fluids of this Table intimately mixed together ; such a Pipe would attract the Parts of Oil and ardent Spirits more strongly than those of Water, and suck in more Parts of the two former than of the latter. The Fluid therefore drawn out of the heterogeneous Fluid by
this

this Pipe, would be different from the Fluid drawn out of it by a small Glass Pipe; for two Fluids will be different, when they either consist of different Parts, or of the same Parts mixed in different Proportions.

Now since Pipes of different Natures draw off different Fluids from one and the same heterogeneous Fluid; it follows, that the discerning Pipes of the Glands, according to their different Natures and Dispositions, suck in various Juices from the Blood, which is a heterogeneous Fluid consisting of a great Variety of Parts. And consequently, the *Proposition* is true.



PROPOSITION XXXI.

IF Human Bodies have the same Number of corresponding Glands,
if

*if those Glands have the same Number of corresponding secerning Pipes arising out of corresponding Blood-Vessels, if the Lengths of corresponding Pipes be as the Lengths of the Bodies, if the Bodies be situated alike with respect to the Horizon, their Hearts be alike free from the Influences of disturbing Causes, and their Blood alike saturated with Parts fit for Secretion; the Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded, of the sesquuplicate Ratios of the Diameters of corresponding Blood-Vessels, and of the subduplicate Ratios of the Forces which move the secerned Humours through corresponding secerning Pipes, directly; and of the subduplicate Ratios of the Lengths of the Bodies, inversely. If Z, z denote the Quantities discharged by two corresponding Glands in a given Time; F, f the Forces which
move*

move the Humours through two corresponding fecerning Pipes; D, d the Diameters of two corresponding Blood-Vessels; and L, l the Lengths of the Bodies; I say, that $Z. z :: D \sqrt{\frac{DF}{L}}. d \sqrt{\frac{df}{l}}.$

For, allowing the Suppositions made in this *Proposition* to be true, it is evident, that the Quantities of Humour discharged by corresponding Glands in a given Time, will be as the Quantities discharged by any of their corresponding fecerning Pipes in that Time: But the Quantities discharged by corresponding fecerning Pipes in a given Time, will be as the Squares of their Diameters, and as the Velocities of the Humour flowing through them, taken together; or as the Squares of the Diameters of the Blood-Vessels out of which the Pipes arise, and as the

the Velocities of the Humour flowing through the Pipes, taken together; because the Diameters of the Pipes are as the Diameters of the Blood-Vessels out of which they arise; and the Velocities of the Humour flowing through corresponding Pipes, will by *Prop. 1.* be in Ratios compounded of the direct subduplicate Ratios of the Forces which move the Humour through them; and of the inverse subduplicate Ratios, of the Diameters and Lengths of the Pipes, or of the Diameters of corresponding Blood-Vessels and Lengths of the Bodies: And therefore, the Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded of the duplicate Ratios of the Diameters of corresponding Blood-Vessels and of the subduplicate Ratios of the Forces which move the Humour thro' cor-

I i

respond-

responding fecerning Pipes, directly; and of the subduplicate Ratios of the Diameters of corresponding Blood-Vessels and of the Lengths of the Bodies, inverſly; that is,
 $Z. z :: D^2 \sqrt{\frac{F}{DL}}. d^2 \sqrt{\frac{f}{dI}}.$ But $D^2 \sqrt{\frac{F}{DL}}.$
 $d^2 \sqrt{\frac{f}{dI}} :: D \sqrt{\frac{DF}{L}}. d \sqrt{\frac{d f}{I}}:$ And there-
 fore, $Z. z :: D \sqrt{\frac{DF}{L}}. d \sqrt{\frac{d f}{I}}.$

Cor. 1. If this *Proposition* be true, and if the moving Forces of corresponding fecerning Pipes be as their Diameters, or as the Diameters of corresponding Blood-Vessels; the Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded of the duplicate Ratios of the Diameters of corresponding Blood-Vessels directly, and of the subduplicate Ratios of the Lengths of the Bodies inverſly. And the mean

Quan-

Quantities of Humour discharged in a given Time, will be in the subduplicate Ratios of the Lengths of the Bodies. If $F. f :: D. d$; then will $Z. z :: \frac{D^2}{\sqrt{L}}. \frac{d^2}{\sqrt{l}}$. And since by *Cor.*

4. *Prop.* 12. the mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, are in the subduplicate Ratios of the Lengths of the Bodies; if D, d denote the mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, and Z, z the mean Quantities of Humour discharged by corresponding Glands in a given Time; then $Z. z :: \sqrt{L}. \sqrt{l}$.

Cor. 2. If this *Proposition* be true, and if the moving Forces of corresponding fecerning Pipes be as the internal Surfaces of the Pipes, that is, as their Diameters and Lengths

taken together, or as the Diameters of corresponding Blood-Vessels and Lengths of the Bodies taken together; the Quantities discharged by corresponding Glands in a given Time, will be in the duplicate Ratios of the Diameters of corresponding Blood-Vessels. And the mean Quantities discharged by corresponding Glands in a given Time will be as the Lengths of the Bodies. If $F. f :: D L. d l$; then will $Z. z :: D^2. d^2$. And, supposing D, d, Z, z to denote mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, and mean Quantities of Humour discharged by corresponding Glands in a given Time; then $Z. z :: L. l$.

Cor. 3. If this *Proposition* be true, and if the moving Forces of corresponding secerning Pipes be as the Capacities of the Pipes, or as the
Capa-

Capacities of corresponding Blood-Vessels; the Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded of the duplicate and subduplicate Ratios of the Diameters of corresponding Blood-Vessels. And the mean Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies. If $F. f :: D^2 L. d^2 l$; then will $Z. z :: D^2 \sqrt{D}. d^2 \sqrt{d}$. And supposing D, d, Z, z to denote mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, and mean Quantities of Humour discharged by corresponding Glands in a given Time; then, since the mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths are in the subduplicate Ratios of the

the

the Lengths of the Bodies, $Z. z :: L \times L^{\frac{1}{2}}. l \times l^{\frac{1}{2}}.$

Cor. 4. If this *Proposition* be true, and if the moving Forces of corresponding fecerning Pipes be as the Capacities of the Pipes, or as the Capacities of corresponding Blood-Vessels; the Sums of the Quantities discharged by all the corresponding Glands, or any given Number of them, in a given Time, will be in Ratios compounded of the duplicate and subduplicate Ratios of the Diameters of corresponding Blood-Vessels: For, since the Discharges of any two corresponding Glands are in these Ratios; the Sum of the Discharges of all the Glands, or of any given Number of corresponding Glands, will be in the same Ratios. If S, s denote those Sums, then $S. s :: D^2 \sqrt{D}. d^2 \sqrt{d}.$ And if S, s, D, d denote the mean Sums of the Discharges

charges in a given Time and mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, each Mean being taken from a considerable Number of Bodies of the same Length; then, since the mean Diameters of corresponding Blood-Vessels are in the subduplicate Ratios of the Lengths of the Bodies, $S. s :: L \times L^{\frac{1}{2}}. l \times l^{\frac{1}{2}}.$



Of the Discharges of Human Bodies.

PROPOSITION XXXII.

THE Mean Quantities of Food and Discharges in a natural Day, taken from all the Food and Discharges of a Month, are nearly equal in healthful Bodies.

For I have found by statical Experiments, that tho' the Food and Discharges of healthful Bodies be rarely equal in single Days; yet the mean Quantities in a natural Day, taken from all the Food and Discharges of a Month, are always nearly equal. And therefore, the *Proposition* is true.

Cor.

Cor. 1. If N, n denote the mean Quantities of Food in a natural Day of two healthful Bodies, taken from their whole Quantities of Food in a Month; and $P, U, S; p, u, s$, the mean Quantities of their Perspiration, Urine, and Stool, taken from the whole Quantities of those Discharges in a Month; then by this *Proposition*, N is nearly equal to $P+U+S$, and n nearly equal to $p+u+s$.

Cor. 2. If a healthful Body at all Seasons of the Year take daily the same Quantity of Food in every Month, taking one Day of the Month with another; the daily Sum of the Discharges in every Month, taking one Day of the Month with another, will be likewise nearly the same at all Seasons of the Year.

K k

And

And therefore, if either Perspiration, Urine, or Stool be greater in some Months of the Year than in others; the Sum of the other two will be as much less: Otherwise the Sum of the three could not be given.

The Truth of these two *Corollaries* will farther appear from the following Table.



Months

Months.	Breakfast.	Dinner.	Supper.	Morning.		Afternoon.		Night.		Stool.	Total Urine.	Total Perpiration.	Total Discharges.	Total Food.
				Urine.	Perpiration.	Urine.	Perpiration.	Urine.	Perpiration.					
April.	23 $\frac{1}{2}$	44	16 $\frac{1}{2}$	8 $\frac{1}{2}$	11	17 $\frac{1}{2}$	11 $\frac{1}{2}$	16 $\frac{1}{2}$	16 $\frac{1}{2}$	5 $\frac{1}{2}$	41 $\frac{1}{2}$	36 $\frac{1}{2}$	83 $\frac{1}{2}$	83 $\frac{1}{2}$
May.	23 $\frac{1}{2}$	47 $\frac{1}{2}$	21 $\frac{1}{2}$	7 $\frac{1}{2}$	13 $\frac{1}{2}$	17 $\frac{1}{2}$	11 $\frac{1}{2}$	16 $\frac{1}{2}$	19 $\frac{1}{2}$	7 $\frac{1}{2}$	41 $\frac{1}{2}$	44 $\frac{1}{2}$	93 $\frac{1}{2}$	92 $\frac{1}{2}$
June.	27 $\frac{1}{2}$	48 $\frac{1}{2}$	15 $\frac{1}{2}$	7 $\frac{1}{2}$	15 $\frac{1}{2}$	12 $\frac{1}{2}$	12 $\frac{1}{2}$	14 $\frac{1}{2}$	22 $\frac{1}{2}$	5 $\frac{1}{2}$	33 $\frac{1}{2}$	51 $\frac{1}{2}$	90 $\frac{1}{2}$	90 $\frac{1}{2}$
July.	25 $\frac{1}{2}$	41 $\frac{1}{2}$	15 $\frac{1}{2}$	7 $\frac{1}{2}$	14 $\frac{1}{2}$	10 $\frac{1}{2}$	12 $\frac{1}{2}$	12 $\frac{1}{2}$	19 $\frac{1}{2}$	5 $\frac{1}{2}$	30 $\frac{1}{2}$	46 $\frac{1}{2}$	82 $\frac{1}{2}$	82 $\frac{1}{2}$
August.	22 $\frac{1}{2}$	41 $\frac{1}{2}$	20 $\frac{1}{2}$	7 $\frac{1}{2}$	17 $\frac{1}{2}$	10	13 $\frac{1}{2}$	12 $\frac{1}{2}$	20 $\frac{1}{2}$	4 $\frac{1}{2}$	29 $\frac{1}{2}$	51 $\frac{1}{2}$	85 $\frac{1}{2}$	85 $\frac{1}{2}$
Septem ^r .	18 $\frac{1}{2}$	48	19 $\frac{1}{2}$	7 $\frac{1}{2}$	13 $\frac{1}{2}$	13 $\frac{1}{2}$	11 $\frac{1}{2}$	15 $\frac{1}{2}$	19 $\frac{1}{2}$	5 $\frac{1}{2}$	36 $\frac{1}{2}$	44 $\frac{1}{2}$	85 $\frac{1}{2}$	85 $\frac{1}{2}$
October.	18 $\frac{1}{2}$	45 $\frac{1}{2}$	15 $\frac{1}{2}$	7 $\frac{1}{2}$	9 $\frac{1}{2}$	13 $\frac{1}{2}$	10 $\frac{1}{2}$	16 $\frac{1}{2}$	17 $\frac{1}{2}$	4 $\frac{1}{2}$	37 $\frac{1}{2}$	37 $\frac{1}{2}$	79 $\frac{1}{2}$	80 $\frac{1}{2}$
Novem ^r .	22 $\frac{1}{2}$	40 $\frac{1}{2}$	15 $\frac{1}{2}$	7 $\frac{1}{2}$	8 $\frac{1}{2}$	12 $\frac{1}{2}$	8 $\frac{1}{2}$	16 $\frac{1}{2}$	18 $\frac{1}{2}$	4 $\frac{1}{2}$	37 $\frac{1}{2}$	35 $\frac{1}{2}$	77 $\frac{1}{2}$	77 $\frac{1}{2}$

This Table was made from a Course of Statical Experiments. The natural Day was divided into three Parts, Morning, Afternoon, and Night; the Morning contain'd six Hours from eight to two, the Afternoon six Hours from two to eight, and the Night the remaining twelve Hours. I observed the Food and the Discharges in these three Parts of the Day, every Day for eight Months together; and with the Means taken from all the Food and all the Discharges in the several Months, I compos'd the Table: From which it appears,

First, That Perspiration and Urine vary in their Quantities at different Seasons of the Year, and that as one encreases the other lessens. In *April* and *May* they were nearly equal, only Urine exceeded Perspiration a little in *April*, and was exceeded by it a little in *May*. In
the

the three Summer Months, *June*, *July*, and *August*, taken one with another, Perspiration exceeded Urine in the Proportion of about 5 to 3. In *October* and *November* they were nearly equal again, only Urine exceeded Perspiration a little in *November*. At the End of this Month I was interrupted, and hindered from carrying on the Experiments throughout the whole Year, as I at first intended; but I repeated them for about ten Days in cold frosty Weather, and found that Urine then exceeded Perspiration as much as Perspiration exceeded Urine in Summer.

Secondly, That Stool is but a small Discharge when compared with Perspiration and Urine, and is but little influenced by the Seasons of the Year in healthful Bodies. It was a little larger in *May* than in the other Months, from a gentle *Diarrhœa*, for
about

about twenty Days in that Month. And it was a little less in *October* and *November*, from the Quantity of Food being less in those Months than in the others.

Thirdly, That the daily Food and daily Discharges taken from all the Food and all the Discharges of a Month, are nearly equal at all Seasons of the Year in healthful Bodies, only the Discharges fall a little short of the Food in Autumn, and exceed it a little in the Spring. The Difference between the Food and Discharges at these Seasons, arises from Perspiration being more diminished in Autumn by the Cold of the external Air, than Urine is increased; and more increased in the Spring by the Warmth of the Air, than Urine is diminished. Urine takes up some Time at these Seasons to have its Increase and Diminution made equal to the Diminution and Increase.

Increase of Perspiration. And hence it is that Bodies grow heavier in Autumn and lighter in the Spring; and by Consequence, that they are a little heavier in Winter than they are in Summer. The Change of Weight in Spring and Autumn is not great in healthful Bodies, and probably does not exceed above three or four Pounds; for I have known an Increase of five or six Pounds to have caused a Disease in the latter End of Autumn: But an Increase of four Pounds in two Months is at the Rate of about an Ounce only in a Day: And the same Increase in three Months is at the Rate of only about two third parts of an Ounce in a Day, taking one Day with another.

A Change is continually made in the Weight of a growing Body; but if we consider the Quantity and Time of its Growth, we shall find
its

its Food and Discharges in a natural Day to be very nearly equal. For if a Child newly born weighs 12 Pounds, and in twenty Years (which I shall suppose to be the Time of growing) come to weigh 168 Pounds; the Food will exceed the Discharges in a natural Day, taking one Day of the whole Time of its Growth with another, by something more than the third part of an Ounce. 'Tis true a healthful Child from its feeding plentifully, sleeping much, and wanting Exercise, grows much more the first half Year than it does afterwards in the same Compass of Time; and yet even then there is but little Difference between the Food and Discharges in a natural Day, taking one Day with another. For if its Weight when it is born be doubled in the first half Year, the Food will exceed the Discharges by little more than

than an Ounce in a Day, taking one Day with another. Therefore the Food and Discharges in a natural Day, taking one Day with another, are nearly equal in growing Bodies.

And we may likewise observe a great Change to be frequently made in the Weights of grown Bodies in the Compass of a few Years; but if we consider the Quantity of the Change, and the Time in which it is made; we shall find little Difference between the Food and Discharges in a natural Day, taking one Day of that Time with another. For if a grown Body gain in Weight 50 Pounds in five Years Time, the Food will not exceed the Discharges by half an Ounce in a natural Day, taking one Day of that whole Time with another.

PROPOSITION XXXIII.

Supposing the same Things as are supposed in the 31st Proposition and its 3^d Corollary; and that the Quantities discharged by Stool in a natural Day, taken from the whole Quantities of that Discharge in a Month are in the same Proportion as the daily Discharges of other corresponding Glands taken from their whole Discharges in a Month; the Sum of the Discharges by Perspiration, Urine, and Stool in a natural Day, taken from their whole Quantities in a Month, will in healthful Bodies of different Lengths be in Ratios compounded of the duplicate and subduplicate Ratios of the Diameters of corresponding Blood-Vessels, that is, $P+U+S. p+u+s :: D^2 \sqrt{D}. d^2 \sqrt{d}.$

For

For the Sums of Perspiration and Urine in a natural Day, taken from their whole Quantities discharged in a Month, are in that Proportion by the 4th Corollary of the 31st Proposition: And the Quantities discharged by Stool in a natural Day, taken from the whole Quantities of that Discharge in a Month, are by Supposition as the daily Discharges of other corresponding Glands taken from their whole Discharges in a Month: And therefore, the Sums of the three Discharges in a natural Day, taken from the wholes of their respective Quantities in a Month, will be in the same Proportion, that is, $P+U+S. p+u+s :: D^2 \sqrt{D}. d^2 \sqrt{d}.$

Cor. 1. If the Diameters of corresponding Blood-Vessels be in the subduplicate Ratios of the Lengths of the Bodies; the Sums of the Quantities of Perspiration, Urine, and

L 1	2	Stool
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Stool discharged daily by healthful Bodies of different Lengths, when each Quantity is taken from the whole of that Discharge for a Month, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies, If $D. d :: \sqrt{L}, \sqrt{l}$, then will $P+U+S. p+u+s :: L+L^{\frac{1}{4}}. l+l^{\frac{1}{4}}$.

If this *Proposition* obtains in healthful Bodies; this *Corollary* will also obtain, when the Diameters of corresponding Blood-Vessels are in the subduplicate Ratios of the Lengths of the Bodies. They are in this Proportion in perfectly regular and well-proportioned Bodies, when they are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes; and the mean Diameters of corresponding Blood-Vessels of all healthful Bodies

dies of different Lengths, when each Mean is taken from the Diameters of those Vessels in a considerable Number of Bodies of each Length, are likewise in the same Proportion: And therefore, the mean Sums of the Quantities of the Discharges in a natural Day of healthful Bodies of different Lengths, when the Quantity of each Discharge is taken from its whole Quantity in a Month, will be in Ratios compounded of the simple and subquaduplicate Ratios of the Lengths of the Bodies: But those Sums of the Discharges are equal to the mean Quantities of Food in a natural Day, taken from the whole Quantities of Food in a Month, by *Cor. 1. Prop. 32*: And by Consequence, the mean Quantities of Food in a natural Day of healthful Bodies of two different Lengths, will be in Ratios compounded of the simple
and

and subquadruplicate Ratios of those Lengths. This Proportion obtains nearly in the *Royal* and *Blew-Boys Hospital*. For upon inquiring into their Food I found, that taking one Day of the Week, and consequently one Day of the Month, with another, the Quantities of Food taken daily by Bodies whose Lengths are 69 and 54 Inches, are 109 and $85\frac{1}{2}$ *Averdupois* Ounces: But these Quantities of Food are nearly in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies; only the Food of the Boys compared with that of the Men, is greater than in this Proportion by about $5\frac{1}{4}$ Ounces in a Day; which may be owing to the Food of the Boys being something more liquid than the Food of the Men, and to their using more Exercise. In the Food of the Boys, the liquid part is to the solid part a
little

little more than 3 to 1; and in that of the Men a little more than $2\frac{1}{2}$ to 1.

Lengths of the Bodies in Inches.	The Lengths into the biquadrate Roots of the Lengths.	Whole Quantities of Food or Discharges in a natural Day in <i>Averdup.</i> Ounces.
72	2097	115
69	1988	109
66	1881	$102\frac{3}{5}$
60	1670	$91\frac{1}{2}$
54	1463	80
48	1263	69
42	1069	$58\frac{3}{5}$
36	882	48
30	702	$38\frac{1}{2}$
24	531	29
18	371	20

This Table in its third Column contains the mean Quantities of Food, or mean Quantities of the Discharges,

Discharges, in a natural Day, of healthful Bodies of the Lengths set down in the first Column. I computed it by the second Column, which contains the Products of the Lengths and biquadrate Roots of the Lengths of the Bodies, taking 109 *Averdupois* Ounces as a proper Quantity of Food for well-proportioned Bodies 69 Inches in Height, on Supposition that the liquid part of the Food to the solid is in the Proportion above-mentioned. The Food of very young Children, as being wholly liquid, should be more than is assigned them by this Table; but what the exact Quantity is I know not for want of Experiments.

Cor. 2. If this *Proposition* be true, as it appears to be by the last *Corollary*; the Sums of the Discharges by Perspiration, Urine, and Stool,
in

in a natural Day, taken from their whole Quantities in a Month, will in Bodies of equal Lengths be in Ratios compounded of the simple and subquadruplicate Ratios of their Quantities of Blood. For the Squares of the Diameters of corresponding Blood-Vessels are as the Quantities of Blood in Bodies of equal Lengths, that is, $D^2. d^2 :: Q. q$; and the Square-Roots of the same Diameters, are as the biquadrate Roots of the Quantities, that is, $\sqrt{D}. \sqrt{d} :: Q^{\frac{1}{4}}. q^{\frac{1}{4}}$: And therefore, $P+U+S. p+u+s :: Q \times Q^{\frac{1}{4}}. q \times q^{\frac{1}{4}}$.

For Instance, if the Quantities of Blood in two healthful Bodies of the same Length be as 3 to 2, then $P+U+S. p+u+s :: 19741. 11892$. If the Length of the Bodies be six Feet, and the Quantity of Food in a Day of that Body which has the

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greater

greater Quantity of Blood be 116 Ounces; the Quantity of Food in a Day of the other Body will be about 70 Ounces.



PROPOSITION XXXIV. Problem V.

TO determine the Proportion of Perspiration to Urine, at different Seasons of the Year, at different Times of the natural Day, under different Kinds and Degrees of Exercise, in Bodies of different Ages, and Bodies nourished by different Kinds of Food.

I. Perspiration with respect to Urine is greater in Summer than in Winter. It was near three times as great in the Body from which the Table in *p.* 259 was made, and it is generally greater, tho' not in
the

the same Proportion, in healthful Bodies. A warm Air warms the Skin and increases Perspiration, and a cold Air cools the Skin and lessens Perspiration; but as Perspiration increases or lessens, Urine on the contrary lessens or increases by that Table. The Proportion of Perspiration to Urine is regulated by the Heat of the Skin; and as far as the Heat of the Skin is increased or lessened by the Heat or Cold of the external Air, the Proportion of Perspiration to Urine will be increased or lessened by the Heat or Cold of the external Air. Accordingly, I have observ'd Perspiration to have been only equal to, nay sometimes to have fallen short of, Urine in the Summer-Time, in Bodies which have been little exposed to the Heat and Cold of the external Air. And as far as I can judge from the Observations I have made,

this chiefly happens in Bodies whose Skins are naturally cool by a spare Diet, or a languid Motion of the Blood, or both.

II. From the Table *p.* 259 it appears, that Urine is always greater in the Afternoon than in the Morning; that Perspiration during the warm Season is less in the Afternoon than in the Morning, and that both are greater in the Day than in the Night. But as the Man from whom that Table was made, walked some Hours every Day, and generally more in the Morning than in the Afternoon; we cannot from that Table determine these Discharges, or their Proportions to one another, at different Times of the Day, in Bodies which are at Rest. To obtain these nearly, I took the Quantities of Perspiration and Urine discharged by two healthful Men B
and

and D, in the several Hours of the Day for four Days together in very hot Weather, and with the mean Quantities of the Discharges in those Hours, composed the following Table.

Hours.	B		D	
	Perfpiration.	Urine.	Perfpiration.	Urine.
6	$1\frac{7}{8}$	$0\frac{1}{10}$	2	I
7	$1\frac{5}{6}$	I	$1\frac{2}{3}$	I
8	2	I	$1\frac{1}{2}$	$1\frac{1}{3}$
9	2	$1\frac{3}{6}$	$1\frac{4}{3}$	$1\frac{3}{10}$
10	2	$1\frac{1}{2}$	$1\frac{9}{10}$	I
11	$1\frac{3}{4}$	I	$1\frac{2}{3}$	I
12	$2\frac{1}{3}$	I	$1\frac{4}{3}$	I
1	$2\frac{1}{3}$	$1\frac{1}{4}$	$1\frac{1}{2}$	I
2	2	I	$1\frac{1}{2}$	I
3	$3\frac{1}{4}$	$1\frac{1}{2}$	2	I
4	$2\frac{1}{3}$	2	$1\frac{1}{2}$	$1\frac{1}{7}$
5	$2\frac{1}{3}$	2	$1\frac{4}{3}$	I
6	$2\frac{2}{3}$	2	2	I
7	2	2	2	I
8	$2\frac{1}{3}$	$2\frac{1}{3}$	2	I
9	$2\frac{2}{3}$	$1\frac{2}{3}$	$1\frac{1}{2}$	$1\frac{1}{2}$
10	$2\frac{1}{3}$	$1\frac{2}{3}$	$1\frac{1}{2}$	$1\frac{1}{2}$

B took 86 Ounces of Food in a Day, and D only 63 : They both eat their Breakfast at eight a Clock in the Morning, dined at two, and supped at eight at Night. It is to be observed, that the Numbers corresponding to the Hour 6 in the Morning, are the mean Quantities of Perspiration and Urine which were drawn off from the Blood in every Hour of the Night, taking one Hour with another.

Setting aside Exercise, and supposing the natural Day to be divided into three equal Parts, Morning, Afternoon, and Night, and the Morning to begin at six a Clock; the Quantities perspired by B and D in the Morning, Afternoon, and Night, were nearly by this Table, 16, 20, 15, and 13, 14, 16; and the Quantities of Urine made by these Bodies in the same Times, were nearly 9, 15, $7\frac{1}{2}$, and 8, $8\frac{1}{2}$, 9. The Proportions

ons of Perspiration to Urine in these Times, were 177, 133, 200, in B; and 162, 164, 177, in D. Hence we learn, that the Proportion of Perspiration to Urine, is greater in the Night when Bodies are at Rest than in the Day-time; that there is no great Difference in this Proportion in these Times, in Bodies which eat sparingly and drink but little Wine, which as the Case of D; and that in Bodies which eat plentifully and drink Wine, this Proportion is often less in the Afternoon than in the Morning, which was the Case of B. Wine in most Bodies increases the Discharge by Urine; and as that Discharge increases, the Proportion of Perspiration to it will necessarily lessen; unless Perspiration be increased in the same Proportion as Urine is increased, which I believe very seldom happens. Hence we may judge of the
Pro-

Proportion of Perspiration to Urine at different Times of the natural Day, in Bodies which are at Rest; and at the same time see, that notwithstanding the Inequalities of this Proportion in different Parts of the natural Day, the Proportion of Perspiration to Urine in the whole natural Day, is nearly the same at the same Season of the Year in healthful Bodies; it was nearly 162 in B, and 168 in D.

III. The Proportion of Perspiration to Urine, is increased by all those Exercises which increase the Motion of the Blood and warm the Skin. Two Men of nearly the same Height and Weight walked a Mile in half an Hour, and in that Time each perspired about $3\frac{1}{2}$ Ounces, which was about three times as much as they ordinarily perspired in the same Time in the Heat of Summer with-

without Exercise. This Degree of Exercise gave a glowing Warmth to the Skin; it did not make them sweat, but would have caused a gentle breathing Sweat, had it been continued much longer. The same Men walked above two Miles in half an Hour, and in that Time one perspired nine Ounces, and the other eight, which was about eight times as much as they ordinarily perspired in the same Time in the Heat of Summer without Exercise. This Degree of Exercise made them sweat profusely. A third Man, who was fat and much taller than either of the others, walked two Miles in half an Hour, and in that Time perspired thirteen Ounces and a half, which was about nine times as much as his Summer's Perspiration in the same Time without Exercise. And a Boy seven Years old, who without Exercise perspired

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half

half an Ounce in half an Hour in the Heat of Summer, by walking at such a Rate as gave a gentle Warmth to his Skin, but did not make him sweat, perspired about three times as much in the same Time. At the Beginning of the Exercise of Walking I have observed, that Urine has been increased as well as Perspiration; but on continuing the Exercise, Urine in a very little Time has decreased, and grown less than it was before the Exercise, from the large Discharge which was made by the Skin. If we suppose the Quantity of Urine not to be lessened by Exercise, as it may not in Persons who by Drink supply the Loss which is made by Perspiration, then will the Proportion of Perspiration to Urine be 6 to 1, in Persons who walk at such a Rate as to give a glowing Warmth to their Skins but not to cause Sweat, and 16 to 1

in

in Persons who walk at such a Rate as to sweat profusely, on Supposition that the Proportion of Perspiration to Urine is 2 to 1 in the Heat of Summer. The Exercise of Riding increases Perspiration, but neither so suddenly, or in so great a Degree, as the Exercise of Walking, as appears from the following Instance. A healthful Man upwards of ninety Years of Age, who commonly without Exercise discharged four or five times as much by Urine as he did by Perspiration, observed that in the Night, after riding several Hours the Day before, he always perspired as much as he discharged by Urine. In this Case therefore, Perspiration to Urine was increased by Riding in the Proportion of 4 or 5 to 1.

IV. The Proportion of Perspiration to Urine in Bodies of different

rent Ages will be greater or less, as the external Heat of the Body is greater or less; But the external Heat of the Body is less in old Bodies than in others: And therefore, the Proportion of Perspiration to Urine will be less in old Bodies than in others. In the old Man above-mentioned, this Proportion was less than in Bodies in the Vigour of their Age in the Heat of Summer, in the Proportion of 1 to 8 or 10.

V, The Proportion of Perspiration to Urine in Bodies nourished by different Kinds of Meats and Drinks will be greater or less, as those Meats and Drinks are fitted to warm or cool the Skin by warming or cooling the Blood, and increasing or lessening its Motion. As to Drinks, Water and watry Liquors drunk hot warm the Skin and increase

crease Perspiration; and drunk cold cool the Skin, and increase Urine. Three or four Quarts of Chalybeate Waters will pass off by Urine in many Bodies in less than three Hours Time. Wine and other fermented Liquors drunk cold and in large Quantities frequently pass off very quick by Urine, but not altogether so quick as cold Water; and drunk hot they increase Perspiration. Water impregnated with Nitre is colder and more diuretick than plain Water. As to Meats, those which are dry and warming increase Perspiration; and those which are moist and cooling increase Urine. Ripe Apples increase Perspiration, as appears from the following Instance. The old Man above-mentioned, whose Perspiration in the eighty-sixth Year of his Age was not above $\frac{1}{4}$ th part of his Urine, by eating three quarters of a Pound of mellow

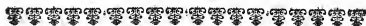
mellow Apples at Night with Bread, brought his Perspiration to be nearly equal to his Urine, less only in the Proportion of 13 to 16. That this Change in Perspiration was owing to the Apples, appeared from hence, that on leaving them off, his Perspiration grew less, and returned to what it was before he began to eat them.

From these Instances it appears, that the Proportion of Perspiration to Urine, is increased or lessened by Meats and Drinks, as they increase or lessen the Heat and Motion of the Blood.





SECTION IV.



Of the Effects of various Fluids, of Age, of different Kinds of Weather, and of Exercise, on animal Fibres.



PROPOSITION XXXV.

IF an animal Fibre be extended by a Force acting uniformly upon it, its Strength will be directly as that Force, and inversely as the Extension caused by it in a given Time: And if the Fibre be of a given Sort of Matter, and its Extension caused by the Force in a given Time be small; its Strength then will be very nearly as

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the

the Square of its Diameter directly, and as its Length inversly. If S denotes the Strength of a Fibre, F the extending Force, E its Extension caused by the uniform Action of that Force in a given Time, D its Diameter, and L its Length; then S will be as $\frac{F}{E}$; and if the Fibre be of a given Sort of Matter, and its Extension be small, then S will be very nearly as $\frac{D^2}{L}$.

For the Strength of a Fibre will be greater, when either a greater Force is required to extend it thro' the same Space, or the same Force is required to extend it thro' a less Space, in a given Time: And therefore its Strength will be as the extending Force directly, and as the Extension caused by the uniform Action of that Force in a given Time

Time inverſly, that is, S will be as $\frac{F}{E}$. And by meaſuring the Diameters and Lengths of Hairs, and taking their Extenſions cauſed by the uniform Action of Forces in a given Time, I found that in ſmall Extenſions the Ratio of the extending Force to the Extenſion cauſed by it in a given Time, is very nearly equal to the Ratio of the Square of the Diameter of a Hair to its Length; that is, $\frac{F}{E}$ is very nearly equal to $\frac{D^2}{L}$. Therefore the *Propoſition* is true.

Cor. If the extending Force be given, the Strength of a Fibre will be inverſly as its Extenſion cauſed by the uniform Action of that Force in a given Time. If F be given, S will be as $\frac{1}{E}$.

I examined the Strengths of different Kinds of Fibres, namely Hairs, Fibres of Silk, and Nerves of Animals; and finding them all to be affected by the same Fluids in like manner but in different Degrees, I chose human Hairs as the fittest for Experiments, and from them composed this Section.

The Hair I used in composing the two following Tables, was that of a healthful young Woman 22 Years of Age. And in order to discover how it was affected by different Fluids, I used such Hairs only whereof equal Lengths were equally extended by the same Force in a given Time, that is, such whereof a Length of 10 Inches was extended by a given Weight through 5 Divisions of a Scale, in which an Inch was divided into 40 equal Parts. And when I had wet one of those Hairs with some Fluid for one Minute,

nute, I took its Extension when wet in the Divisions of the same Scale. And having got these two Extensions, and supposing E to express the Extension of the wet Hair; its Degrees of Strength when dry and when wet, will be as $\frac{1}{5}$ and $\frac{1}{E}$, by this *Cor.* or as 1 and $\frac{5}{E}$, or as 100000 and $\frac{500000}{E}$. And therefore the Strength of the dry Hair being expressed by 100000, its Strength when wet with that Fluid, will be express'd by $\frac{500000}{E}$.

I measured the Extensions of the Hairs by means of an *Apparatus* thus contrived. ABCD represented a Ruler, whole Length AD is about two Feet, its Breadth DC about three quarters of an Inch, and its Thickness CV one quarter of an Inch. The upper End is received

ceived into a Block, so as that the Ruler hangs perpendicularly to the Plane of the Horizon. IKL is a sliding Plate of Brass so contrived, as that it may be fixed any where on the Ruler by means of a Screw M pressing the Plate of Brass NO against the Side BCV. From the Middle of this sliding Plate projects a small Cylinder represented at r, having an Hole drill'd thro' it at right Angles to its Axis and to the Horizon; and the Axis of the Cylinder receives a Screw which presses against the Center of its Basis. The lower End of the Ruler is faced with a thin Plate of Ivory seven Inches in Length; each Inch is divided into 40 equal Parts, ab, bc, &c. and each of those Parts by means of a diagonal Scale into four others. pRq is a small piece of Brass 8 Grains in Weight, having a Groove on its upper Part, where
it

it is pierced with a very small Hole in order to receive the End of a Hair under the Screw o; and pq represents an human Hair for cutting the Divisions on the Scale PC.

Having pass'd one End of an Hair thro' the small Hole at R, and fasten'd it by turning the Screw o, I drew the other End by help of a small bearded Wire through the Hole in the Cylinder r, and fixed it by the Screw n, so as always to have an Interval of 10 Inches between those Screws. Then on the Groove of the Brass pRq I hung a Scale with a Weight W, and observed the encreased Length or Extension of the Hair when dry in two Minutes of Time, caused by the uniform Action of the given Weight of 300 Grains, which was the Sum of the Weights of the Scale, of W, and of the little Brass pRq. If this Extension either exceeded or fell short of 5 Divisions of the

the

the Scale, the Number pitch'd upon for the given Extension of a Hair when dry, I threw this Hair away and try'd others, till I met with one which had exactly that given Extension. I then took off the Scale, and gently rub'd the Hair from End to End with a Feather dipp'd in some Fluid, and continued thus wetting it for one Minute; at the End of which Time, I put on the Scale again, and observed the Extension produc'd in two Minutes, the Hair being kept wet, by gently rubbing it with the wet Feather all the Time. Sometimes I got the given dry Extension by taking a Mean of two or more dry Extensions which were near it, and the wet Extension corresponding to it by taking a Mean of the wet Extensions of the same Hairs. And after I had found the Extension of a Hair wet with Water to be 35, its Extension when dry being

being 5: I frequently did not take the dry Extensions, but took the Extensions of Hairs, first wet with Water, and afterwards, when they were dried, with other Fluids. And if the Extension of a Hair wet with Water, was a few Divisions either above or below 35, I got the true Extension of a Hair wet with some other Fluid corresponding to the Extension 35 when wet with Water, by this Analogy. As the Extension greater or less than 35 is to 35, so is the Extension corresponding to that greater or less Extension when a Hair is wet with some other Fluid, to the Extension it would have had when wet with that Fluid, had its Extension when wet with Water been 35. Thus I got the Extensions of Hairs, and from those Extensions composed the following Tables.

TABLE I.

	Extension when dry.	Extension when wet.	Strength of a Fibre.
Dry	5		100000
Wet with Mutton Suet melted		$5\frac{1}{10}$	98039
Fat of a Turkey melted		$5\frac{1}{8}$	97561
Oil Olive		$5\frac{1}{2}$	96154
Oil of Turpentine		$5\frac{1}{4}$	95238
Oil of Fennel		$5\frac{1}{4}$	95238
Butter melted		$5\frac{1}{4}$	95238
Salt of Tartar <i>per deliquium</i>		$6\frac{1}{10}$	79365
A strong Solution of com- mon Salt }		$6\frac{1}{4}$	74074
Spirit of Wine rectified		7	71428
Rum		$9\frac{1}{2}$	52631
A strong Solution of Sal- armoniac }		$9\frac{1}{2}$	52631
Good Brandy		10	50000
A strong Solution of Sal-gem		$12\frac{1}{2}$	40000
A strong Solution of Nitre		20	25000
A strong Solution of fine Sugar		20	25000
Meath		$22\frac{1}{2}$	22222
Cream of Cow's Milk		$23\frac{1}{10}$	21459
Juice of Mazzard Cherries		$24\frac{1}{2}$	20272
Gravy of roast Beef		26	19231
Cow's Milk skim'd		26	19231
A strong Solution of Green Vitriol }		27	18518
Juice of a ripe Nectarin		$27\frac{1}{2}$	18116
Juice of a Lemon		28	17857
Juice of a ripe Peach		$28\frac{1}{2}$	17544
A strong Solution of Alum		$28\frac{1}{2}$	17544
French Claret		29	17241
A strong Solution of Salt of Tartar }		$29\frac{1}{2}$	16949
Vinegar		$29\frac{1}{2}$	16949
Juice of common Cherries		$29\frac{1}{2}$	16949
Sheep's Gall		30	16666
Juice of a green Apricock		$30\frac{1}{2}$	16393

Juice

TABLE I.

	Extension when dry.	Extension when wet.	Strength of a Fibre.
Wet with Juice of a ripe Apple	5	30 $\frac{1}{2}$	16393
Juice of raw Beef		31	16129
Gravy of roast Veal		31	16129
Boyl'd Water, when cold		31	16129
Gravy of boyl'd Mutton		31	16129
Juice of Raspberries		31	16129
Juice of Billberries		31 $\frac{3}{4}$	15748
Juice of Currans		32	15625
Juice of Gooseberries		32	15625
Juice of Parsley		32	15625
Dew in June		32 $\frac{1}{2}$	15384
Juice of raw Turneps		32 $\frac{7}{8}$	15290
Juice of Sorrel		32 $\frac{1}{4}$	15267
Juice of a very ripe Apricock		33	15151
Juice of raw Carrots		33	15151
Juice of Cucumbers		33	15151
Juice of Purslain		33	15151
Juice of Lettice		33	15151
Juice of Mint		33	15151
Juice of Fennel		33	15151
A strong Infusion of Mus- tard-seed in Water }		33 $\frac{1}{2}$	15075
Juice of raw Onions		34	14706
Juice of raw Potatoes		34	14706
Juice of raw Cabbage		34 $\frac{1}{2}$	14492
Water cold		35	14285
Juice of raw Parsneps		35	14285
Juice of Dandelion		35	14285
Juice of Sage		35 $\frac{1}{4}$	14184
Juice of raw Selery		36 $\frac{1}{4}$	13888
Juice of Water Cresses		37	13514
Juice of Scurvy-Grass		38	13158
Spirit of Sal-armoniac		72 $\frac{1}{2}$	6896
Water hot		80	6250
Spirit of Vitriol		87	5747

TABLE II.

	Extension when dry.	Extension when wet.	Strength of a Fibre from Ex- periments Mixture.	Its Streng. according to the
Dry	5		100000	69658
Wet with 2 Parts of Oil-Olive, and 1 part of Sheep's Gall, mix'd			18518	38888
2 Parts of good Brandy, and 1 part of Sheep's Gall, mix'd	27	34	14706	19861
2 Parts of Cream of Cows Milk, and 1 part of Sheep's Gall, mix'd	34	34	14706	17049
2 Parts of French Claret, and 1 part of Sheep's Gall, mix'd	33	33	15151	20370
2 Parts of Meath, and 1 part of Sheep's Gall, mix'd	26		19231	54938
2 Parts of a strong Solution of common Salt, and 1 part of Sheep's Gall, mix'd	9.15		54644	17460
2 Parts of Lemmon Juice, and 1 part of Sheep's Gall, mix'd	28		17857	58465
2 Parts of Salt of Tartar <i>per deliquium</i> , and 1 part of Sheep's Gall, mix'd	61.0		79365	66401
2 Parts of Oil-Olive, and 1 part of Spirit of Sal-armoniac, mix'd	47		10638	35632
2 Parts of good Brandy, and 1 part of Spirit of Sal-armoniac, mix'd	40		12500	

TABLE II.

	Extention when dry.	Extention when wet.	Strength of a Fibre from Ex- periments	Its Streng- th according to the Mixture.
Wet with 2 Parts of Cream of Cow's Milk, and 1 part of Spirit of Sal-armoniac, mix'd	5	46	10870	16605
2 Parts of French Claret, and 1 part of Spirit of Sal-armoni- niac, mix'd		45	11111	13793
2 Parts of Meath, and 1 part of Spirit of Sal-armoniac, } mix'd		30½	16393	17113
2 Parts of a strong Solution of common Salt, and 1 part of } Spirit of Sal-armoniac, mix'd		10	50000	51681
2 Parts of Lemon Juice, and 1 part of Spirit of Sal-armoni- niac, mix'd		29½	16949	14203
2 Parts of Salt of Tartar <i>per deliquium</i> , and 1 part of Spirit } of Sal-armoniac		8½	60975	55209
2 Parts of a strong Solution of Nitre, and 1 part of Spirit } of Sal-armoniac, mix'd		52	9615	18965

OBSERVATIONS *on the* Tables.

Obs. 1. **A**Nimal Fibres are stronger when they are dry, than when they are wet with any of the Fluids of these Tables.

Obs. 2. By the first Table, Fats and Oils strengthen animal Fibres out of the Body more than ardent Spirits; ardent Spirits strengthen them more or less, as they are more or less rectified; Cream of Cows Milk strengthens them more than skim'd Milk, and fermented Liquors more than cold Water: But ardent Spirits and fermented Liquors of all Kinds are composed of Oil and Water united by Fermentation, the Water, by means of some saline Spirits with which 'tis impregnated, dissolving

solving the Oil, and volatilizing it by the Action; Cream of Cows Milk contains more oily Parts than skim'd Milk; and even Water is not void of oily Parts, forasmuch as out of it grow all vegetable and animal Substances which contain such Parts in their Composition: And therefore it is rational to attribute the strengthening Powers of all these Fluids to their oily Parts.

Obs. 3. Dew, which is composed of watry Vapours condensed, strengthens animal Fibres little more than cold Water: But Salt of Tartar *per deliquium* strengthens them much more than the strongest Solution of the same Salt in cold Water: And therefore this Salt in deliquating draws something out of the Air besides Water. What that is, may be gathered from *Prop. 24.* and the following Chymical Experiments

ments and Inferences drawn from them.

“ A Solution of Silver in *Aqua*
 “ *fortis* poured upon Copper, dis-
 “ solves the Copper and lets go the
 “ Silver; a Solution of Copper
 “ poured upon Iron, dissolves the
 “ Iron and lets go the Copper; a
 “ Solution of Iron poured upon *La-*
 “ *pis Calaminaris* or Zink, dissolves
 “ the *Lapis Calaminaris* or Zink
 “ and lets go the Iron; a Solution
 “ of Zink poured upon Chalk,
 “ Crabs Eyes or Oyſter-ſhells dis-
 “ solves the Chalk, Crabs Eyes or
 “ Oyſter - ſhells and lets go the
 “ Zink; a Solution of Chalk, Crabs
 “ Eyes or Oyſter-ſhells mix'd with
 “ Spirit of Sal - armoniac, unites
 “ with the Spirit and lets go the
 “ Chalk, Crabs Eyes or Oyſter-
 “ ſhells; and this Mixture poured
 “ upon Salt of Tartar *per deliquium*,
 “ dissolves the Salt and lets go the
 “ volatile

“ volatile Spirits. Hence the acid
 “ Particles of *Aqua fortis* are at-
 “ tracted more strongly by Cop-
 “ per than by Silver, and more
 “ strongly by Iron than by Copper,
 “ and more strongly by *Lapis cala-*
 “ *minaris* or Zink than by Iron,
 “ and more strongly by Chalk,
 “ Crabs Eyes or Oyſter-ſhells than
 “ by Zink, and more strongly by
 “ Spirit of Sal-armoniac than by
 “ Chalk, Crabs Eyes or Oyſter-
 “ ſhells, and more strongly by Salt
 “ of Tartar *per deliquium* than by
 “ Spirit of Sal-armoniac.

Hence it appears, that Salt of
 Tartar *per deliquium* attracts Acids
 more ſtrongly than Metals do, or
 any Body we know of: But the Air
 abounds with acid Particles, by *Prop.*
 24: And therefore the watry Moi-
 ſture imbibed from the Air by this
 Salt when it deliquates, muſt neceſ-

farily be strongly impregnated with acid Particles.

And if the Acid of the Air be the sole Cause of the great Excess of the strengthening Power of Salt of Tartar *per deliquium* above that of the strongest Solution of the same Salt in Water, as I think it must be allow'd to be; then such as receive most of that Acid into their Blood in a given Time, will, *ceteris paribus*, have the strongest Fibres. Hence animal Fibres are strongest in frosty Weather, are stronger in Winter than in Summer, in cold Countries than in hot, in dry Weather than in moist, and in Winds which blow from the *North* and *East*, than in Winds blowing from the *South* and *West*.

Obs. 4. By the second Table, Spirit of Sal - armoniac and Sheep's Gall,

Gall, lessen the strengthening Powers of Oils, ardent Spirits, Cream, and fermented Liquors; and the Spirit lessens them more than the Gall: But by the second Observation Oils, ardent Spirits, Cream, and fermented Liquors have their strengthening Powers from their oily Parts: And therefore Spirit of Sal-armoniac and Sheep's Gall must lessen the strengthening Powers of those Fluids by producing some Change in their oily Parts. Hence Gall in the Intestines of Animals, lessens the strengthening Power of the oily Part of the Aliment in its Passage thro' them.

Obs. 5. The Fats of Animals are rather more strengthening than Oil-Olive, which shews that the oily Part of the Nourishment regains in the Blood that Part of its strengthening Power which it loses in the Intestines by being mix'd with the

Gall: But the Acid of the Air has a very great strengthening Power, by *Obs.* 3; and the Blood of Animals has a constant Supply of this Acid by means of Respiration, by *Prop.* 24: And therefore it is rational to attribute the Recovery of the strengthening Power of the oily Part of the Nourishment destroy'd by the Gall in the Intestines, to the Acid of the Air.

And if Oil, when its strengthening Power is destroy'd or greatly lessened by Gall, can recover it again by being mix'd with the Acid of the Air, we may allow this Acid to be the immediate Cause of the strengthening Powers of Oils and all Fluids abounding with oily Parts. For Spirit of Sal-armoniac very much lessens the strengthening Powers of Oils and Fluids abounding with oily Parts, by the second Table: But this Spirit attracts Acids very strongly by
the

the Experiments in *Obs.* 3: And therefore it is rational to think that it lessens the strengthening Powers of the said Fluids by drawing of an Acid from their oily Particles; This Acid must be the same with the volatile Acid of the Air which enters the Composition of all vegetable and animal Substances: And consequently Oils and Fluids abounding with oily Particles, have their strengthening Powers from the Acid of the Air united with those Particles. And that animal Fibres have their Strength from the same Cause will be shewn in the next Observation.

Obs. 6. Spirit of Sal - armoniac used alone weakens animal Fibres much more than cold Water; and it weakens them gradually, that is, if they be extended successively being suffered to contract after every Extension,

Extension, they will grow weaker in every succeeding Extension for a considerable Time. For an Hair kept wet with this Spirit, was weaker in the 25th Extension than in the first in the Proportion of 1 to 2; and another Hair kept wet with it, was weaker in the 60th Extension than in the first in the Proportion of 10 to 23. I try'd this last Hair four Days after when wet with the same Spirit, and found that it had not recovered any part of its lost Strength in that Time; but was then as weak in the first Extension, as it was in the 60th in the first Trial. Hence Spirit of Sal-armoniack gradually weakens the Power of the Cause upon which the Strength of animal Fibres depends: But this Spirit from its attracting Acids very strongly, greatly lessens the strengthening Power of oily Particles by drawing off the Acid of the Air from
them,

them, by *Obs.* 5 ; and animal Fibres contain an Acid in their Composition, forasmuch as they contain Salt ; and Salt is composed of Acid and Earth united by Attraction, as Sir *Isaac Newton* has shewn, *Opt.* p. 360 : And therefore Spirit of Sal-armoniac gradually lessens the Strength of animal Fibres, by gradually drawing off an Acid from their earthy Parts, upon which Acid the Strength of Fibres depends. This Acid must be the same with the Acid of the Air, because Animals have a constant Supply of this Acid both from their Food, and by means of Respiration.

Obs. 7. The Juices of Water-Cresses and Scurvy - Grass, weaken animal Fibres something more than cold Water, but much less than Spirit of Sal-armoniac ; and they probably do it, as that Spirit does, by
drawing

drawing off a small Portion of the Acid from the earthy Parts of the Fibres.

Obs. 8. Spirit of Vitriol weakens animal Fibres gradually, like Spirit of Sal-armoniac. For a Hair kept wet with this Spirit was weaker in the 12th Extension than in the first in the Proportion of 71 to 15. The Way this Spirit weakens animal Fibres may be this: The earthy Part of a Fibre may attract this Spirit more strongly than its own Acid from whence it has its Strength, and not being able to hold both, may let go its own to close with this, and so lose its Strength. The Case here is much like that described by Sir *Isaac Newton* in these Words. “When
 “ Spirit of Vitriol poured upon
 “ common Salt or Salt-petre makes
 “ an Ebullition with the Salt and
 “ unites with it, and in Distillation
 “ the

“ the Spirit of the common Salt or
 “ Salt-petre comes over much easier
 “ than it would do before, and the
 “ acid Part of the Spirit of Vitriol
 “ stays behind; does not this argue
 “ that the fix'd Alcaly of the Salt
 “ attracts the acid Spirit of the Vi-
 “ triol more strongly than its own
 “ Spirit; and not being able to hold
 “ them both, lets go its own?
Opt. p. 353.

Obs. 9. Rectified Spirit of Wine
 strengthens animal Fibres at first
 much more than cold Water; but
 if Fibres be kept constantly wet with
 it, they will grow weaker in every
 Extension for some Time. For a
 Hair kept constantly wet with it,
 was weaker in the 24th Extension
 than in the first in the Proportion
 of 26 to 7; but it was then stronger
 than if it had been wet with Water
 in the Proportion of 35 to 26: So
 R r that

that tho' Hairs wet with this Spirit grow weaker and weaker in every Extension, yet as far as I have try'd they never come to be so weak as when wet with Water. The Reason may be, that the spirituous Part of this Fluid evaporates much faster than its watry Part: For this will leave the Hair more saturated with Water and less with Spirit in every succeeding Trial, and so gradually weaken it, tho' never so much as cold Water. The Strength of a Hair wet with this Spirit in the first Table, was taken from the first Extension, in which we may suppose the Hair to be mostly saturated with this Spirit. But the Strengths of Hairs wet with Spirit of Sal-armoniac and Spirit of Vitriol were taken from the last Extensions of the Trials I made, as they ought to be, on account of the Change made in the Texture of the Fibres by those Spirits.

Obs.

Obs. 10. Spirit of Sal-armoniac and the Gall of Animals scarce alter the strengthening Power of the strongest Solution of common Salt in Water; which argues that the acid Part of common Salt is more strongly attracted by the Alcaly of that Salt, than it is by Spirit of Sal-armoniac and the Gall of Animals. Hence common Salt is of a very permanent Nature, and a great Preserver of animal and vegetable Substances from Putrefaction when they are saturated with it.

Obs. 11. Spirit of Sal-armoniac and the Gall of Animals mix'd with Salt of Tartar *per deliquium*, encrease its strengthening Power; and this they do by imparting some Acid to that Salt. For Salt of Tartar *per deliquium* attracts Acids more strongly than Spirit of Sal-armoniac does, by the Experiments in *Obs. 3*;

and consequently, by the stronger Attraction, it not only retains its own Acid, but draws some Acid from the Salts of the Spirit and Gall, and has its strengthening Power encreased thereby.

Obs. 12. Vegetable Juices taken one with another, strengthen animal Fibres something more than cold Water. The Juices of Fruits strengthen them something more than the Juices of Roots or Herbs; and the Juices of green Fruits a little more than the Juices of Fruits which are ripe. In general, vegetable Juices strengthen less than the Gravies of flesh Meats, and Water less than fermented Liquors; whence Persons who live upon flesh Meats and fermented Liquors have, *cæteris paribus*, stronger Fibres than Persons who live upon Vegetables and Water. Air is much worse, from
putrid

putrid Vapours and Exhalations, in Cities than in the Country; on which account, a Diet of flesh Meats and fermented Liquors taken in moderate Quantities, is more necessary in Cities than in the Country, to strengthen the Fibres and preserve Bodies from Diseases. Fresh Air is a great Strengthenener of the Fibres, and a great Preserver of animal Fluids from Putrefaction; and consequently does not require so generous a Diet to keep Bodies in Health, as an Air corrupted by putrid Vapours and Exhalations.

Obs. 13. So then, by the foregoing Observations, animal Fibres seem to have their Strength, and Fluids their strengthening Powers, from the Acid of the Air, united with their component Particles by virtue of its strong Attraction.

The

The Acid of the Air and other acid Spirits, seem to have their attractive Powers from the Particles of Light united with their component Particles. For Sir *Isaac Newton* has shewn from Experiments and Observations, that both Acids and Light attract fix'd Bodies more strongly than they do Water, that the attractive Powers of the Particles of Light in Proportion to their Quantities of Matter are exceedingly great, for Instance, the Attraction of a Ray of Light in Proportion to its Quantity of Matter, is above 1000000000000000000 times greater than the Gravity of a Body at the Surface of the Earth is in Proportion to its Quantity of Matter, and that Light enters the Composition of all Bodies; from all which it is rational to attribute the attractive Powers of acid Particles to the Particles of Light united with them.

From the immense Attraction of the Rays of Light in Proportion to their Quantities of Matter, Sir *Isaac Newton* makes the following Inference.

“ Tanta autem vis in Radiis, non
 “ potest non ingentes effectus ob-
 “ tinere in illis materiæ particulis,
 “ quibuscum in corporibus compo-
 “ nendis conjuncti sint; ad efficien-
 “ dum, ut particulæ illæ se invicem
 “ attrahant, et inter se moveantur.

And he expresses much the same Opinion in *Qu.* 30. of his *Opticks* in these Words. “ Are not gross
 “ Bodies and Light convertible into
 “ one another, and may not Bodies
 “ receive much of their Activity
 “ from the Particles of Light
 “ which enter their Composition?
 “ For all fix’d Bodies being heated
 “ emit Light so long as they con-
 “ tinue sufficiently hot, and Light
 “ mutually stops in Bodies as often
 “ as

“ as its Rays strike upon their Parts,
“ as we shew’d above.

Obs. 14. Mr. *Hales* in his *Vegetable Staticks* has shewn that volatile Salt of Sal-armoniac distill’d absorbs true permanent Air, or destroys part of its Elasticity: But this Salt in Spirit of Sal-armoniac attracts Acids so strongly as to be able to draw them off from Metals and Earths dissolved by them, by the Experiments in *Obs. 3*; and the Particles of true permanent Air are of a fix’d and earthy Nature: And therefore it is rational to think, that the volatile Salts of Sal-armoniac distill’d absorb true permanent Air, or destroy its Elasticity, by drawing off an Acid from its component Particles. And if so, then the same Cause which gives the Particles of fix’d Bodies an attractive Power when they touch, whereby

whereby they stick together, gives them a repulsive Power whereby they fly or endeavour to fly asunder, when by Heat or Fermentation they are removed to small Distances from one another.



PROPOSITION XXXVI.

A Nimal Fibres by Age encrease in Density and Strength, and lessen a little in Magnitude.



Proof by EXPERIMENTS.

Experiment I.

THE mean Strengths of the Hairs of three Females of the Ages 8, 22, 57 Years, were as the Numbers 10309, 17967, and 25000, S f when

when the Hairs were dry : And single Hairs of these Persons of the same Strength when dry, were of the Strengths 7812, 14285, and 22222, when they were wet with cold Water. The mean Densities of these Hairs were 10390, 11470, and 12947, the Density of Water being 10000. And their mean Diameters were $\frac{1}{300}$, $\frac{1}{317}$, and $\frac{1}{350}$ part of an Inch.

Exp. 2. The mean Diameter of the Hairs of 4 Girls, whose mean Age was seven Years and a half, was $\frac{1}{382}$ part of an Inch, and their mean Density 10348. And the mean Diameter of the Hairs of 4 old Women, whose mean Age was 58 Years, was $\frac{1}{398}$ part of an Inch, and their mean Density 12692. Therefore the *Proposition* is true.

Cor.

Cor. 1. The Strengths of animal Fibres in Proportion to their Densities, are less in young Bodies than in old. For the mean Strengths of the Hairs of the three Females in the first *Experiment* in Proportion to their mean Densities, are as the Numbers 99220, 156643, and 193095.

Cor. 2. The Strengths of animal Fibres in Proportion to the Quantities of Matter in equal Lengths of them, are less in young Bodies than in old. For the mean Quantities of Matter in equal Lengths of the Hairs used in the first *Experiment*, computed from their mean Diameters and mean Densities, are as the Numbers 11544, 11414, and 10568; and their mean Strengths in Proportion to their mean Quantities of Matter, are as the Numbers 89301, 157412, and 236563.

SCHOLIUM.

From Fibres growing stronger as Bodies grow older, without any Increase in their Quantities of Matter ; it is evident that the Power which makes the Particles of Fibres to cohere and resist extending Forces, must arise from some very subtile Matter, whose Particles are endued with very great attractive Forces ; which subtile Matter can be no other than Light. For the Particles of Light, from their exceeding Smallness, may enter the Composition of Bodies in great Quantities without sensibly increasing their Weights, and, from their strong attractive Powers, may make the Particles of the Bodies with which they are united cohere or stick together with great Force. Hence Fibres will grow stronger perpetually as Bodies advance in Age, from their still getting

ting more and more of these active Particles from Food, Exercise, Fire, and that great Fountain of Light the Sun; and consequently Bodies will grow old soonest, whose Fibres by the aforesaid Ways get the greatest Quantity of these active Particles into their Composition in a given Time. The Truth of all which appears from the following Observations. Old Woods burn more vehemently than young Woods of equal Dryness, which argues that they contain more Light in their Composition. Plants abound more with Oil and less with watry Juices, in Autumn than in Spring; but Oil contains much more Light in its Composition than Water. Women sooner leave off Child-bearing, and Bodies grow old sooner, in hot Countries than in cold. Plants of the same Kind sooner come to their full Growth and wither sooner in sunshiny

shiny than in shady Places. And violent Exercise brings on old Age, which consists in an universal Hardness of the Fibres, as *Sanctorius* has observed. This Hardness of the Fibres caused by violent Exercise, may arise chiefly from a greater Quantity of Light imparted to them in a given Time, by a greater Quantity of Food and a greater Quantity of the Acid of the Air. For the watry part of the Food must communicate Light to the Fibres on account of their attracting it more strongly than Water does, by *Obs. 13. Prop. 35.* And if the Acid of the Air be of a watry Nature, and differ chiefly from Water in containing much more Light in its Composition than Water does, as from some Observations is obvious to collect, then this Acid will do the same as the watry part of the Food, and for the same Reason; and granting this, such

such as take most Food, and acquire most of this Acid by Respiration, in a given Time, must, *cæteris paribus*, have the strongest Fibres: But such as use violent Exercise, take more Food and more fresh Air than others: And consequently they will soonest acquire that Strength and Rigidity of the Fibres wherein old Age consists.



PROPOSITION XXXVII.

THE Fibres of Animals are stronger or weaker, as the Air abounds, less or more with watry Vapours or putrid Exhalations, or more or less with acid Particles, or as it is colder or hotter.

1. The Fibres of Animals are stronger or weaker, as the Air abounds less or more with watry Vapours. For all Sorts of Fibres, and most other Bodies, are drier or moist-
er

er as the Air is drier or moister; Woods shrink and become lighter in dry Weather, and swell and grow heavier in wet Weather; and I have found Hairs stretched with a very small Weight to be shorter in dry Weather than in wet, in the Day than in the Night. A Friend made a Hygroscope of a Piece of Sponge thoroughly dried and counterpoised by a Weight equal to it in that State, and observed in general, that from the Sun-rising the Weight of the Sponge decreased till Noon or a little after, and, if the Weather was not moist, stood there till towards Evening, when it began to increase, and increased considerably in the Night; that when the Window was left open in the Evening or Night the Weight increased more; that it increased very much even in the Day on washing the Room next to the Closet where it hung, tho' the Door was
kept

kept lock'd; and that it always increased in wet Weather and decreased in dry Weather. And it has been found by statical Experiments that human Bodies are lighter in dry Weather than in wet Weather, which argues that the Fibres of Animals are affected by the Weather as other Bodies are, or that they are drier or moister as the Air abounds less or more with watry Vapours: But dry Fibres are stronger than wet Fibres by *Tab. 1. Prop. 35*. A Hair was stronger when dry than when wet with cold Water in the Proportion of 100000 to 14285. I wet a Hair with cold Water, and then suffer'd it to dry, and found it to be stronger in the seventh Extension than in the first which was made immediately on leaving off wetting it, in the Proportion of 71 to 34; which shews that wet Fibres grow stronger as they grow drier: And therefore the Fi-

bres of Animals are stronger or weaker, as the Air abounds less or more with watry Vapours.

2. The Fibres of Animals are stronger or weaker as the Air abounds less or more with putrid Exhalations. For Salts become volatile by Putrefaction, by *Schol. Prop.* 29; and consequently when the Bodies of Animals and Vegetables are dissolved by Putrefaction, their Salts become volatile, and ascending into the Air destroy some Part of its Acid and lessen its Elasticity, by virtue of the great Power wherewith they attract acid Particles, and on both these Accounts those Salts weaken the Fibres of Animals more or less, as the Air abounds more or less with them. There may likewise be Differences in the Natures and Powers of these putrid Salts, by which when mix'd with the Blood of Animals they may act very differently both upon it and the

the Fibres, and so cause Epidemick Diseases of various Kinds. But the Effects arising from the different Natures of these Salts, I leave to be determined by farther Experiments and Observations.

3. The Fibres of Animals are stronger or weaker as the Air abounds more or less with acid Particles. The Truth of this appears from the Observations on the *Tables of Prop.* 35.

4. The Fibres of Animals are stronger or weaker, as the Air is colder or hotter. For Cold condenses animal Fibres as well as other Bodies by bringing their Parts nearer together, and Heat rarefies them by removing their Parts to greater Distances from one another: But the nearer the Parts of Fibres are to one another, the greater are the attractive Powers of those Parts, all Attraction being stronger at less Distances than at greater; and the

greater the attractive Powers of the Parts of Fibres are, the greater is the Strength of the Fibres: And therefore the Fibres of Animals are strengthened by Cold and weaken'd by Heat, and consequently are stronger or weaker as the Air is colder or hotter. Accordingly I have found Hairs to be stronger in Winter than in Summer, and they are much stronger when wet with cold Water than when wet with hot Water, by *Tab. 1. Prop. 35*. Therefore the *Proposition* is true.



PROPOSITION XXXVIII.

IF dry Fibres of different Strengths be wetted with Water, or Fibres wet with Water of different Strengths be dried; the Losses of Strength of the first in Proportion to their Strengths when dry, and the Gains of Strength of

of the second in Proportion to their Strengths when wet, will each of them be less in stronger Fibres than in weaker.

Proof by EXPERIMENTS.

FIVE Hairs were extended by a given Weight in equal Times, thro' the Spaces 3, 4, 5, 6, 7, when the Hairs were dry; and thro' the Spaces $7\frac{1}{2}$, $12\frac{1}{2}$, 36, 60, 89, when they were wet with Water. Their Strengths computed from these Extensions, were as the Numbers 3333, 2500, 2000, 1666, 1428, when the Hairs were dry; and as the Numbers 1333, 800, 277, 166, 112, when they were wet. And their Losses of Strength by being wetted, were as the Numbers 2000, 1700, 1723, 1500, 1316; which Numbers likewise express the Gains of Strength which the wet Hairs would have acquired by being dried; for I have found that Hairs wet with Wa-
ter

ter recover the same Degrees of Strength by being dried, which they lose by being wetted. And the Losses of Strength of the dry Hairs by being wetted, in Proportion to their Strengths when dry, were as the Numbers 6000, 6800, 8615, 9003, 9215: And the Gains of Strength of the wet Hairs by being dry'd, in Proportion to their Strengths when wet, were as the Numbers 1500, 2125, 6220, 9036, 11750. Therefore the *Proposition* is true.

Cor. Hence we see the Reason why Persons of weak Fibres are more affected by Changes of Weather from dry to wet and wet to dry, than Persons of strong Fibres. For those must certainly be most affected by these Changes, whose Fibres alter most in their Strength with respect to the Strength they had before the Changes happened. Accordingly
we

we often find Persons of weak Fibres complain of Lowness of Spirits and Pains at the coming on of wet Weather, but seldom observe Persons of strong Fibres to be troubled with those Complaints.



PROPOSITION XXXIX.

I*F the same Fibre both dry and wet be extended and contracted alternately for some Time, it will in both these States lose Part of its Strength by this Motion; and the Loss in a given Time in Proportion to the Strength at the Beginning of the Motion, will be less when the Fibre is dry, than when it is wet.*

Proof by EXPERIMENTS.

I Extended a dry Hair by a given Weight five times successively, taking off the appended Weight after every Extension, and suffering the
the

the Hair to contract as long as it was extending, which was two Minutes of Time. The first Extension was 5 and the last $5\frac{1}{2}$, whence by the first *Proposition* the Strength of the Hair in the first Extension was as 20000, and in the last as 18181; and the Loss of Strength by the Motion as 1819, and the Loss in Proportion to the Strength at the Beginning of the Motion as 909. After this, I wet the same Hair, and kept it wet during five other Extensions, the first of which was 64 and the last 93. The Degrees of Strength corresponding to these Extensions, were as the Numbers 1562 and 1075; and the Loss of Strength by the Motion in this State of the Fibre was as 487, and the Loss in Proportion to the Strength at the Beginning of the Motion as 3118.

I extended another Hair 7 times, both when it was dry and when it
was

was wet with Water, and found the first and seventh Extensions to be 6 and $6\frac{3}{4}$ when it was dry. The Strengths corresponding to these Extensions were as the Numbers 16666, 14815, and the Loss of Strength by the Motion as 1851, and the Loss in Proportion to the Strength at the Beginning of the Motion, as 111. When the same Hair was wet, the first and seventh Extensions were 85 and 102. The Strengths corresponding to these Extensions were as the Numbers 1176, 980, and the Loss of Strength by this Motion was as 196, and the Loss in Proportion to the Strength at the Beginning of the Motion, as 166. Therefore the *Proposition* is true.

Cor. Hence we have one Reason why spare dry Bodies are not so soon tired by Labour and Exercise, as Bodies which are gross and phlegmatick. For the Fibres of the former

are drier than the Fibres of the latter; and consequently, by this *Proposition*, lose less Strength in a given Time in Proportion to their Strength at the Beginning of the Motion, than the others do: But those Bodies must certainly bear Labour and Exercise longest without Fatigue, whose Fibres lose least Strength in a given Time in Proportion to their Strength at the Beginning of the Motion. Another Reason why the former can bear Labour and Exercise longer without Fatigue than the latter, is, that they have lighter Bodies to move, and stronger Muscles to move them.



PROPOSITION XL.

THE *Contraction of a Fibre in a given Time, in Proportion to its Extension caused by a given Weight in the same Time; is something less in stronger*

stronger Fibres than in weaker, both when the Fibres are dry and when wet with Water.

Proof by EXPERIMENTS.

Exp. 1. **T**HE Extensions in 2 Minutes of 2 dry Hairs of a Girl 8 Years of Age, were 7, 21, and their Contractions in the same Time were $6\frac{5}{8}$, 20. And the Extensions of the same Hairs when wet with Water were 72, 118; and their Contractions $71\frac{1}{4}$, 117. And the Contractions in Proportion to their respective Extensions, were as the Numbers 9464, 9523 when the Hairs were dry, and as the Numbers 9895, 9915 when they were wet with Water.

Exp. 2. The Extensions of 2 dry Hairs of a young Woman 22 Years of Age were $4\frac{1}{2}$, 8; and their Contractions in the same Time 4, $7\frac{1}{2}$: And the Extensions of the same

Hairs when wet with Water were 15, 92; and their Contractions $14\frac{1}{8}$, $91\frac{1}{4}$. And their Contractions in Proportion to their respective Extensions were 8888, 9375 when the Hairs were dry, and 9417, 9918, when wet with Water.

Exp. 3. The Extensions of 2 dry Hairs of a Woman 57 Years of Age were 5, $13\frac{1}{2}$, and their Contractions in the same Time $4\frac{1}{2}$, $12\frac{3}{4}$. And the Extensions of the same Hairs when wet with Water were $22\frac{1}{2}$, 77, and their Contractions $21\frac{3}{4}$, $75\frac{3}{4}$. And their Contractions in Proportion to their respective Extensions were as the Numbers 9000, 9444 when the Hairs were dry, and as the Numbers 9666, 9838 when wet with Water. Therefore the *Proposition* is true.

F I N I S

